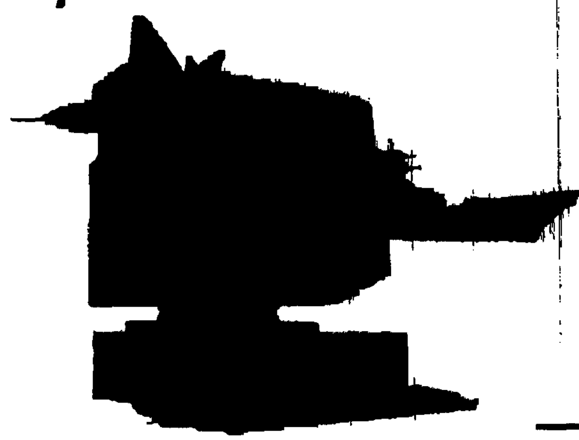
NDIA
NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

1st Annual
Systems Engineering & Supportability *Workshop*

Revised Agenda, Track Schedule and Descriptions, & List of Attendees



San Diego Mission Valley Hilton
September 15 - 17, 1998
San Diego, California

Event #887

With Participation By:

INCOSE

AIAA

Aerospace Industries Association

IEEE

SAE

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FRED L. JONES
Print or Type Name

703-247-2544
Telephone Number

F. L. Jones
Authorized Signature/Date

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First Annual Systems Engineering - Supportability
Conference and Workshop San Diego, CA.

Mission Valley Hilton
14-18 Sept. 98

- **WE HAVE HEARD FROM DR. SANDERS AND MR KRATZ— THEIR MESSAGE IS CLEAR—WE NEED TO FOCUS ON HOW WE SUPPORT, MAINTAIN AND UPGRADE OUR SYSTEMS**

- **THE UNDER SECRETARY OF DEFENSE FOR ACQUISITION REFORM HAS PROVIDED US WITH THE OPPORTUNITY— AND THE ENVIRONMENT TO MODERNIZE AND IMPROVE OUR BUSINESS AND TECHNICAL PRACTICES.**

- **A MAJOR DRIVER BEHIND ACQUISITION REFORM HAS BEEN THE BUDGET. IF WE ARE GOING TO MODERNIZE AND LIVE WITHIN THE BUDGET CONSTRAINTS WE NEED TO FIND PLACES WHERE WE CAN SAVE MONEY. MUCH OF OUR FOCUS HAS BEEN ON REFORMING THE ACQUISITION PHASES OF THE SYSTEM LIFE CYCLE—BUT IN TRUTH THE OPERATIONS AND SUPPORT OR O&S PHASE OF THE SYSTEMS LIFE CYCLE IS WHERE WE SPEND THE LION'S SHARE OF OUR SYSTEMS RELATED DEFENSE DOLLARS. THEREFORE, IT WOULD ONLY MAKE SENSE THAT THIS IS ANOTHER "TARGET OF OPPORTUNITY" THAT IS CRITICAL**

TO REFORM, MODERNIZE AND IMPROVE OUR BUSINESS AND TECHNCIAL PRACTICES.

- SPECIFICALLY, LOOK AT THE HISTORY OF JUST A FEW OF OUR LEGACY SYSTEMS.

CHART

- THIS CHART HAS BEEN USED BY THE LOGISTICS COMMUNITY FOR SOME TIME TO MAKE THE POINT THAT O&S COSTS ARE HIGH PRINCIPALLY BECAUSE OF LOW SYSTEM RELIABILITY THAT HAS IN TURN RESULTED IN MORE SPARES BEING REQUIRED—AND THEREFORE COSTING US MORE MONEY

- WHILE THERE IS SOME TRUTH IN THIS, IT DOES NOT TELL THE WHOLE STORY—O&S COSTS AS WE ALL KNOW ARE MADE UP OF MANY ELEMENTS INCLUDING FUEL, MANPOWER, AMMUNITION, EXISTING SUPPORT INFRASTUCTURE ETC—NOT ALL OF THESE ARE DIRECTLY

TIED TO RELIABILITY EVEN THOUGH IT MAY PLAY A PART IN SOME. OPERATIONAL TEMPO IS ALSO ANOTHER MAJOR CONTRIBUTING FACTOR. IT STANDS TO GOOD REASON THAT THE MORE WE USE A SYSTEM, THE HIGHER THE O&S COSTS ARE GOING TO BE, ESPECIALLY IF THE SYSTEM USES FUEL.

- **BUT THAT IS NOT MY FOCUS. WHEN I LOOK AT THIS CHART, I SEE A BIG OPPORTUNITY.**

- **AS WE CAN SEE—THERE IS AMPLE OPPORTUNITY TO MAINTAIN AND MODIFY THESE SYSTEMS—ESPECIALLY WHEN YOU CONSIDER THE LONGER O&S TIMEFRAME COMPARED TO THE DEVELOPMENT TIMEFRAME.**

- **MOREOVER—WE ARE ACTIVELY TRYING TO SHORTEN THE ACQUISITION LIFE CYCLE..**

- **THE OPPORTUNITY OR CHALLENGE TO THE ENGINEERING COMMUNITY IS THIS—HOW DO WE**

COLLECTIVELY DESIGN A SYSTEM TO BE EFFICIENTLY AND EFFECTIVELY MAINTAINED DURING OPERATION—BUT ALSO—HOW DO WE DESIGN A SYSTEM TO BE EFFICENTLY AND EFFECTIVELY UPGRADED WITH NEW TECHNOLOGY OR CAPABILITY—OR AGAINST A NEW THREAT OVER TIME ?

- **OUR EFFORTS UNDER ACQUISITION REFORM HAVE IMPROVED OUR PRACTICES TO DESIGN AND PRODUCE NEW SYSTEMS EFFICIENTLY AND EFFECTIVELY.**

- **WE HAVE INSTITUTONALIZED IPPD—WE HAVE FORMED IPTS TO BRING THE ACQUISITION LOGISTICIAN INTO THE DESIGN PROCESS—WE HAVE EXPLOITED OPEN SYSTEMS ARCHITECTURES AND REDUCED THE NUMBER OF MANDATORY MILITARY SPECIFICATIONS AND STANDARDS—WE HAVE UPDATED THE ACQUISITION WORKFORCE CURRICULUM AT THE DEFENSE ACQUISITION UNIVERSITY TO REFLECT THESE AND MANY OTHER CHANGES.**

- **I BELIEVE WE HAVE DONE A REASONABLE JOB TO ENSURE THAT ACQUISITION REFORM HAS BEEN PUSHED OUT INTO THE FIELD.**

- **THERE HAVE BEEN ROAD SHOWS, ACQUISITION REFORM STANDDOWN DAYS, WORKSHOPS, SATELLITE BROADCASTS, AND A HECK OF A LOT OF MEDIA EXPOSURE.**

- **BUT WITH ALL THIS ACTIVITY, HAS THE ENGINEERING COMMUNITY—THOSE OF US HERE TODAY—COLLABORATED ON HOW WE CAN COMPLEMENT EACH OTHERS' ACTIVITIES.**

- **SPECIFICALLY, HAVE THOSE OF US ON THE ACQUISITION SIDE OF THE HOUSE SHARED OUR LEESONS LEARNED WITH IPPD—THE USE OF IPTS—OUR EFFORTS TO ADOPT COTS AND OUR VIEWS ON THE ANTICIPATED PAYOFF OF AN OPEN SYSTEMS ARCHITECTURE ?**

- **HAS THE SYSTEM OPERATING/SUSTAINING COMMUNITY SHARED THE LIMITATIONS OF APPLYING CAIV ? THE NUANCE ASSOCIATED WITH USING COTS--- OR OPEN ARCHITECTURES ? THE PRESSURE OF MAINTAININGG AN OPERATIONS TEMPO WHILE TRYING TO DO NORMAL MAINTENANCE OR A SYSTEM UPGRADE. TRYING TO REPLACE OR MAINTAIN PARTS, COMPONENTS OR SUB-SYSTEMS WHERE THE OEM HAS GONE OUT OF BUSINESS OR JUST STOPPED MAKING THE PRODUCT.**

- **I BELIEVE WE HAVE A LOT TO SHARE WITH EACH OTHER—THAT IS THE ACQUISITION AND SUSTAINMENT ENGINEERING COMMUNITIES—THAT'S WHY WE ARE HERE TODAY.**

- **NOW DON'T GET ME WRONG—A LOT OF GOOD WORK AND COMMUNICATIONS HAS AND IS GOING ON. TAKE THE EXAMPLE OF THE NSSN**

CHART

- THE QUESTION WE WANT TO ANSWER TODAY IS—HOW CAN WE DUPLICATE THIS KIND OF GOOD NEWS STORY WITH OTHER SYSTEMS ?

- HOPEFULLY, WE WILL FIND OUT THIS WEEK.

- BEFORE I BRING ON THE PANEL, LET ME SHARE WITH YOU JUST HOW IMPORTANT WE ARE TO THE TECHNICAL COMMUNITY AT LARGE.

- DR. SANDERS AND I ARE OFTEN ASKED TO SPEAK AT VARIOUS WORKSHOPS, SYMPOSIA, ETC. IN THE AREAS OF QUALITY—TEST AND EVALUATION—MANUFACTURING—SOFTWARE—ACQUISITION LOGISTICS—OPEN SYSTEMS—RELIABILITY AND MAINTAINABILITY—MODELING AND

SIMULATION AND OF COURSE SYSTEM ENGINEERING IN GENERAL—JUST TO NAME A FEW.

- THE CONSISTENT THEME WITH ALL THESE FUNCTIONAL DISCIPLINES IS THIS—WE HAVE TO WORK WITH THE DESIGN ENGINEER , THE OPERATORS AND SUSTAINERS TO BE SURE WE ALL UNDERSTAND EACH OTHERS' NEEDS AND REQUIREMENTS.

- IT IS CLEAR—AS I LISTEN TO THE INDIVIDUAL FUNCTIONAL COMMUNITIES—THAT THIS COMMUNITY IS EXPECTED TO EFFECTIVELY AND EFFICIENTLY INTEGRATE THE MANY DISCIPLINES IT TAKES TO DESIGN—DEVELOP----PRODUCE—MAINTAIN AND UPGRADE THE DEPARTMENT'S SYSTEMS.

- THE CHALLENGE IS FOR US TO JUST DO IT.

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V-22 OSPREY - DESIGNED FOR SUPPORTABILITY

Edgar W. Apollo
Boeing - Philadelphia
V-22 Product Assurance Manager

1st Annual NDIA Systems Engineering & Supportability
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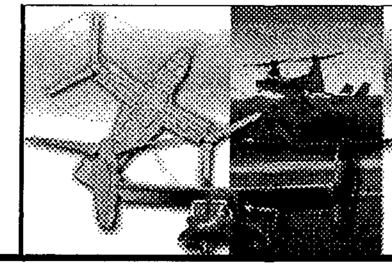
NDIA



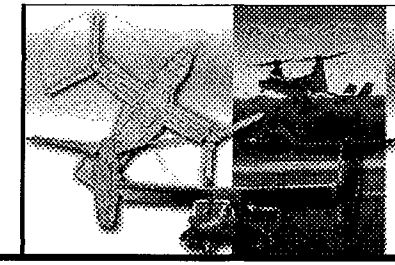
AGENDA

- ***A Different Approach***
  - ***Integrated Product Teams***
- ***Supportability Enhancements***
  - ***Confluence of Requirements***
  - ***Design Influence Tools***
- ***Summary***

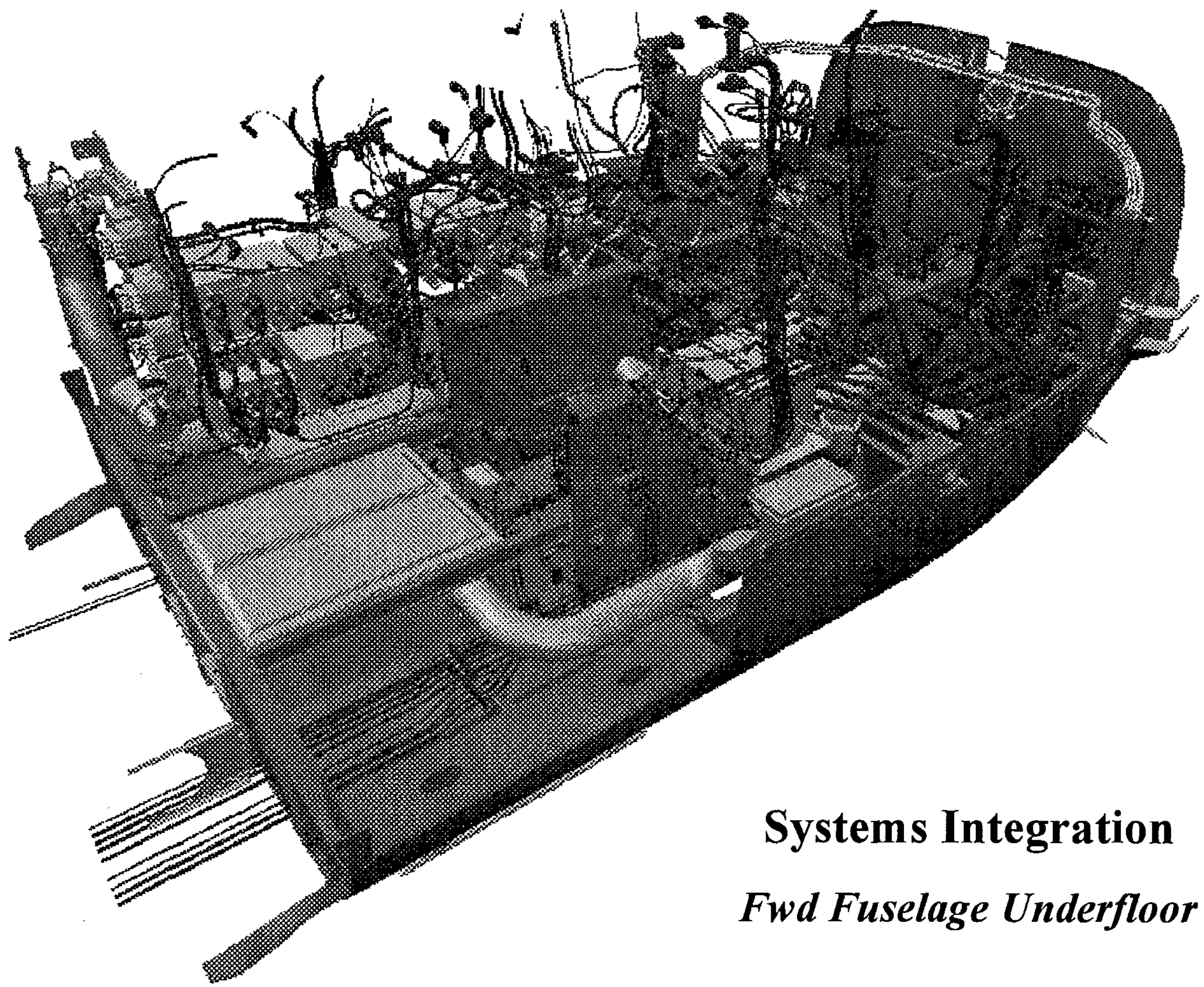
V-22 OSPREY

DESIGNED FOR SUPPORTABILITY

A Different Approach

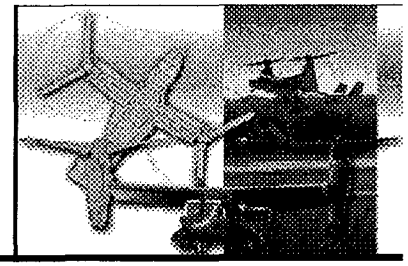


- **What Is So Cost Effective About The Way The V-22 Was Designed And Fabricated?**
- **What Role Did Supportability Play Into Design Decisions?**



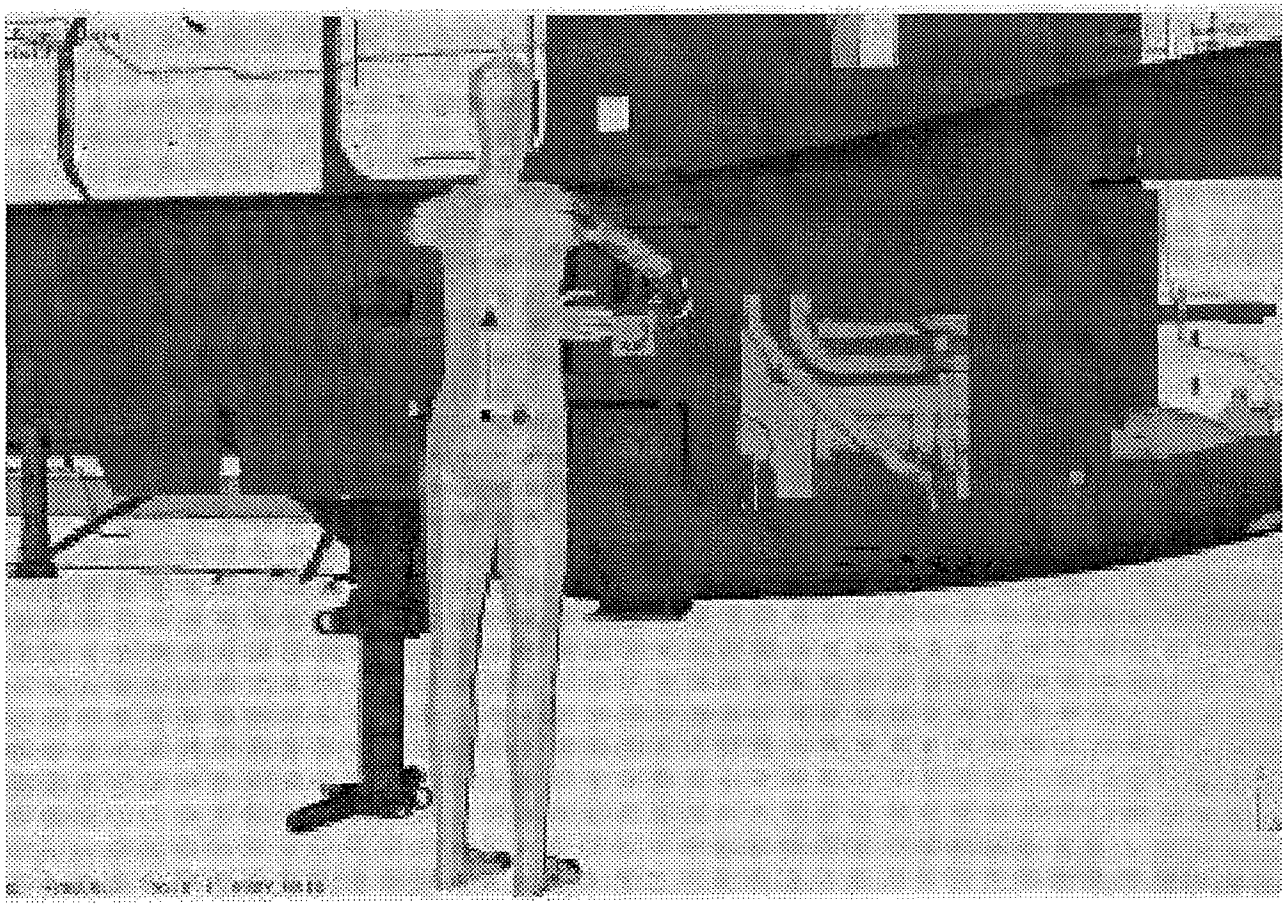
Systems Integration

Fwd Fuselage Underfloor



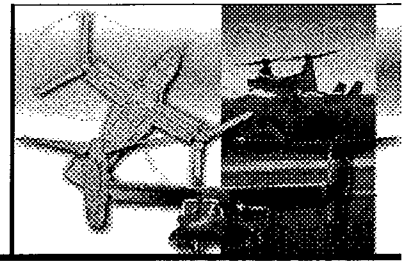
A Different Approach

- **How Has The Maintainer And The Operator Benefited From This New Design Approach?**



V-22 OSPREY

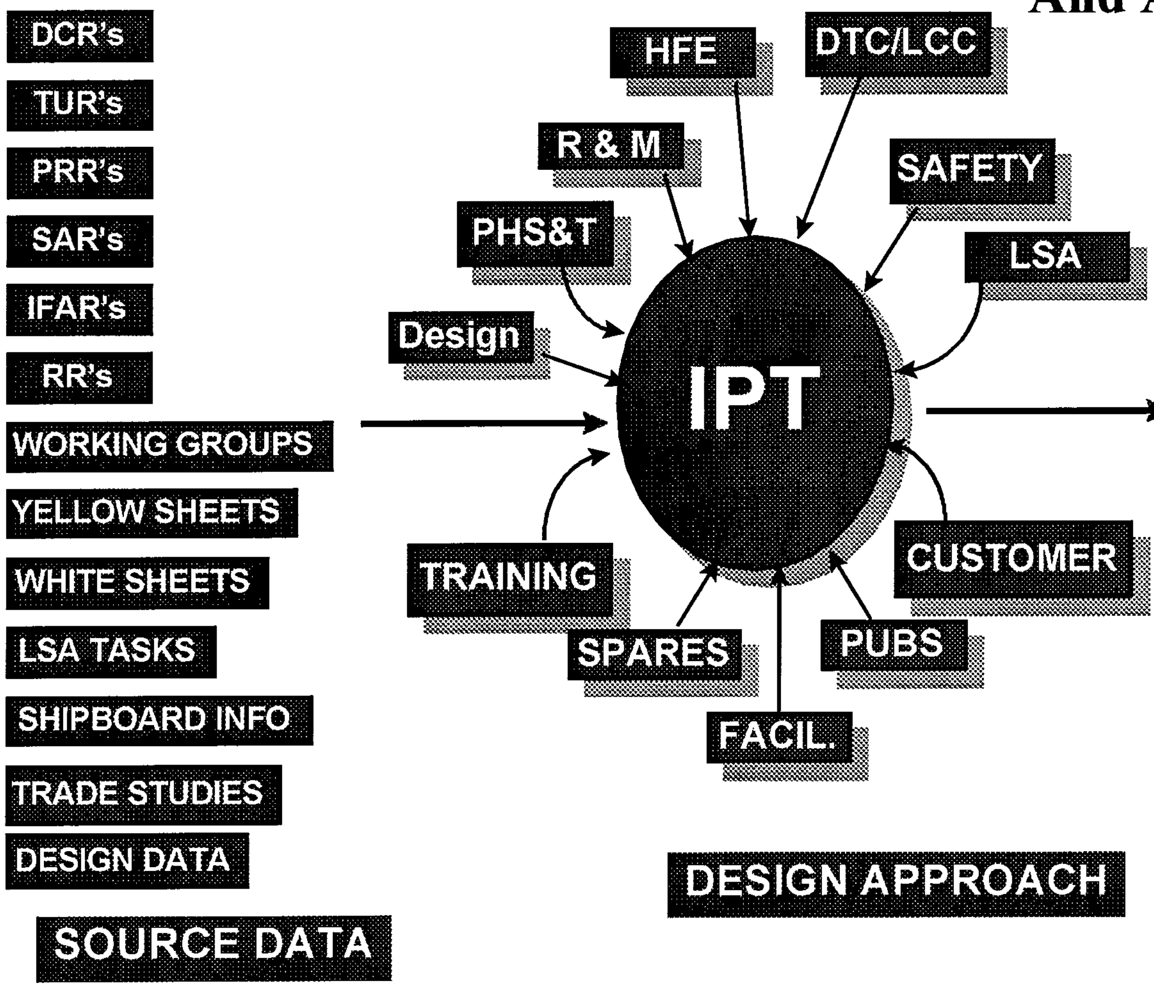
DESIGNED FOR SUPPORTABILITY

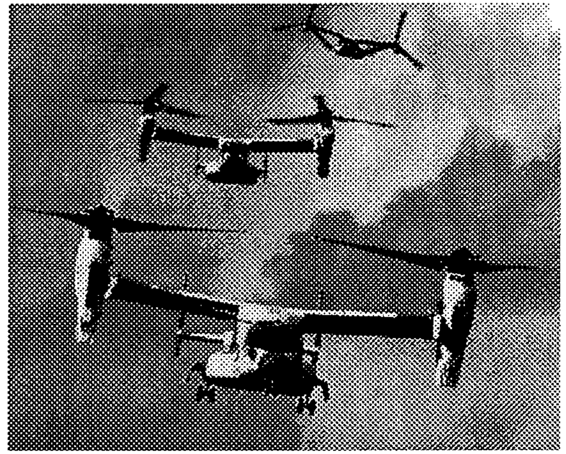


A Different Approach

Integrated Product Teams (IPTs)

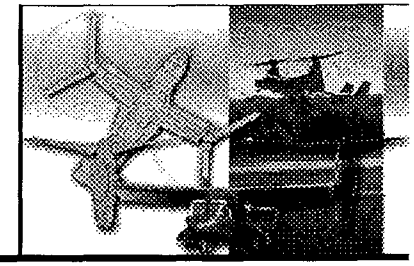
➪ **True Systems Engineering To Maximize Supportability And Affordability Influences**





SUPPORTABLE AIRCRAFT

V-22 OSPREY
DESIGNED FOR SUPPORTABILITY
A Different Approach



Integrated Product Teams

V-22 DESIGN DATA

- SPECIFICATIONS
- PERFORMANCE REQUIREMENTS
- WEIGHTS DATA
- DRAWINGS
- FAILURE RATES
- MAINTAINABILITY DATA
- RELIABILITY DATA
- AVI / ELECIO DATA
- LOADS DATA
- STRESS DATA
- MANUFACTURING TOLERANCES
- MOCKUPS
- STATIC & FATIGUE TESTS
- TOOLING DATA
- DAMAGE LIMITS
- WEAR LIMITS
- REPAIR LIMITS

IS ANALYZED TO DETERMINE PROCEDURES FOR:

- TESTING & TROUBLESHOOTING
- DISASSEMBLY ASSEMBLY
- FAULT ISOLATION
- INSPECTION
- CALIBRATION
- REPAIR
- REWORK
- OVERHAUL

WHICH ARE USED TO IDENTIFY AND DOCUMENT

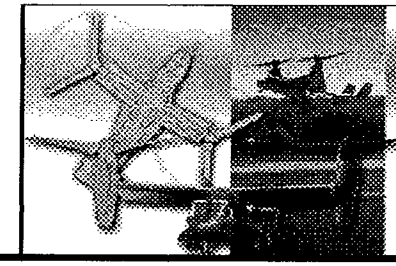
V-22 CUSTOMER SUPPORT RESOURCE REQUIREMENTS

- SUPPORT EQUIPMENT
- TOOLS
- SPARES AND REPAIR PARTS
- MAINTENANCE TRAINING
- OPERATOR TRAINING
- PACKAGING
- HANDLING
- STORAGE
- TRANSPORTATION
- FACILITIES
- TECHNICAL PUBLICATIONS

V-22 OSPREY

DESIGNED FOR SUPPORTABILITY

Supportability Enhancements



➪ *IPT GOAL: To field a V-22 support system which meets all our customer's objectives:*

❶ Identify, flow down, and conduct compliance verification of all Supportability requirements

❷ Optimize Design Controllable Maintenance & Support Parameters - Utilize Design Influence tools

❸ Maximize Built In Test/On Board Diagnostics

❹ Increase Reliability, Maintainability, and Accessibility For Maintenance And Servicing

❺ Reduce Scheduled Maintenance And Repair Actions

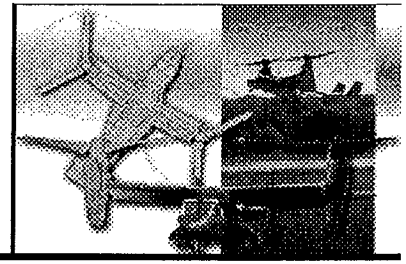
❻ Develop And Implement An On Condition Maintenance Philosophy

❼ Develop (Level IV) Interactive Electronic Technical Manuals (IETMs)

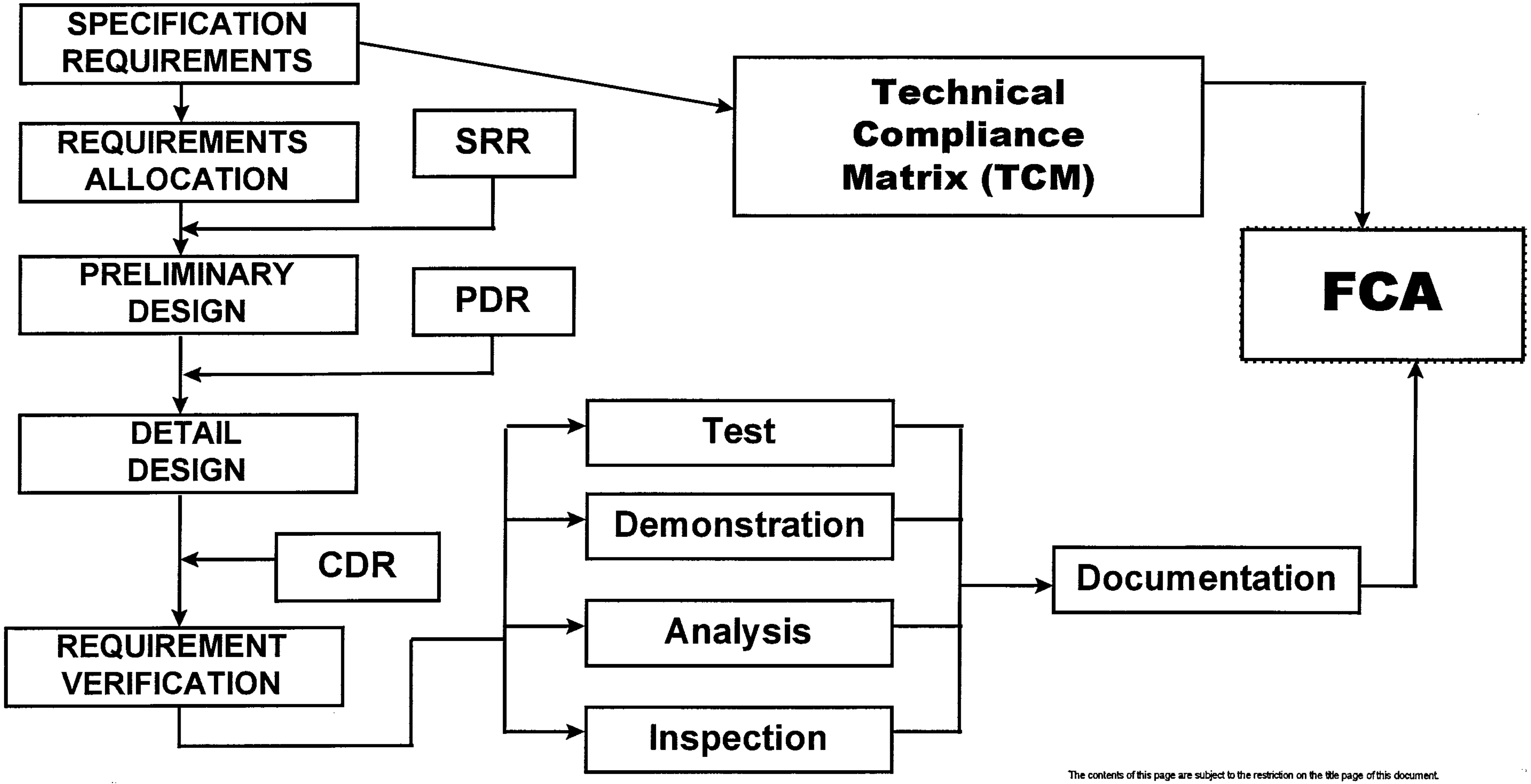
❽ Minimize Support Equipment Requirements

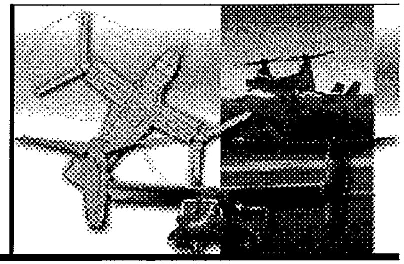
V-22 OSPREY
DESIGNED FOR SUPPORTABILITY

Supportability Enhancements



❶ Identify, flow down, and conduct compliance verification of all Supportability requirements





Supportability Enhancements

❶ Identify, flow down, and conduct compliance verification of all Supportability requirements

FCA

V-22

SD-572-1, Apendix B

I-3.1.2 Mean-Flight-Hours-Between-Design-Controllable-Failures (MFHBFDC). - The hardware reliability of the aircraft weapon system shall have a design threshold MFHBFDC of 4.6, 4.5, 4.4 hours (upper test level, θ_0) for the USMC, USN, and USAF configuration respectively when tested in accordance with Paragraph I-4.3. A design controllable failure is a failure which directly results from and whose frequency is the result of design controllable characteristics.

TCM

Aircraft Level Requirement

Reliability Prediction Report (CDRL A039)

Verification Method = Analysis

Convert MFHBFdc to MFHBFdt to MTBF (operating hours)

Component Flowdown

Derived Requirements

Supplier Specs/SOWs

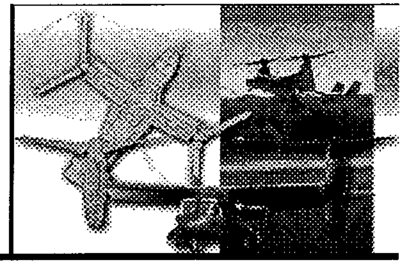
Supplier Predictions

MFDs
FCC
LGCU
IUs
AMC
APU
etc...

Bell Boeing Submittal Letter: JPO-4575-95

NAVAIR Approval Letter: JPO-0743-95

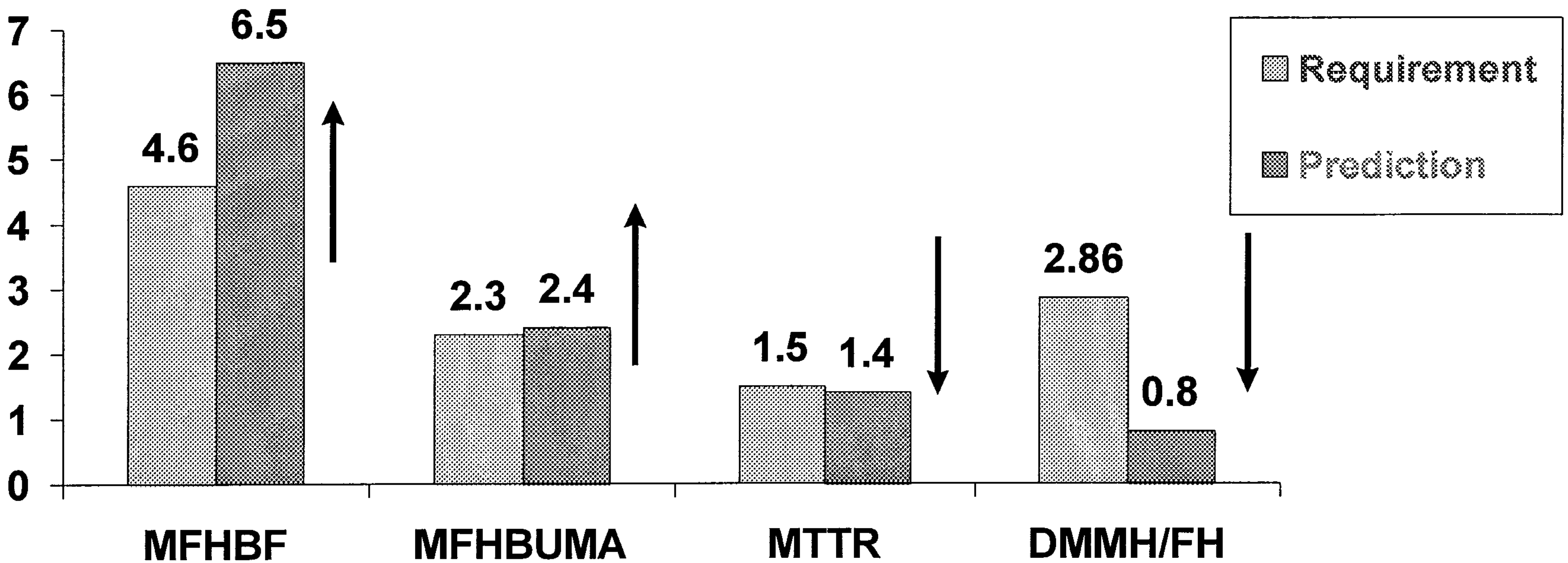
Verification Status: COMPLETE



Supportability Enhancements

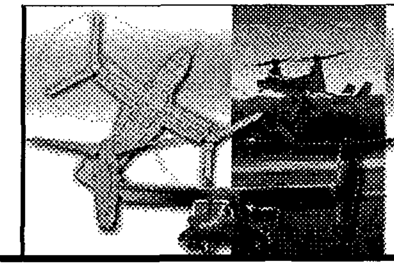
❷ Optimize Design Controllable Maintenance & Support Parameters.

✓ **Predictions at maturity (60K FHrs) For Design Controllable Reliability & Maintainability Are Currently Reflecting Better Performance Than Specification Requirements.**



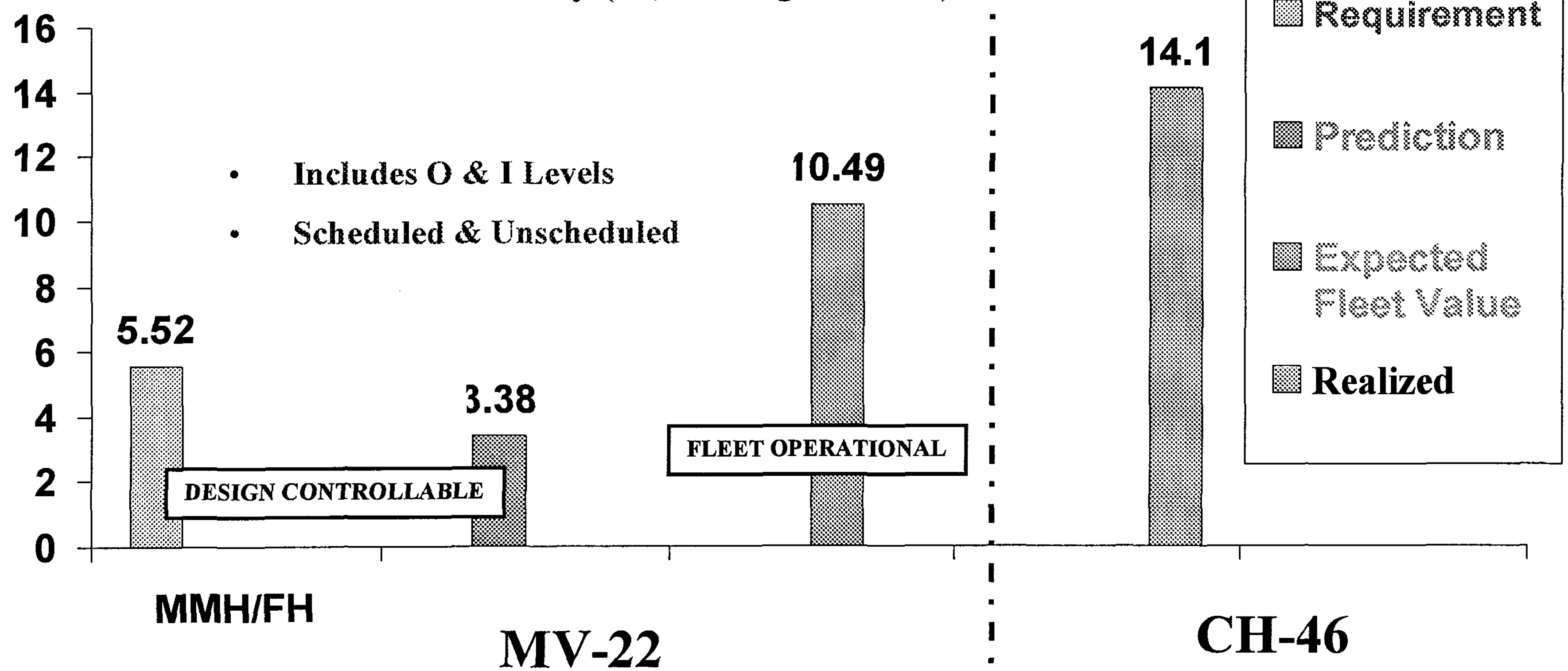
NOTE: Direction Of Arrows Indicate Goodness

Supportability Enhancements



❷ Optimize Design Controllable Maintenance & Support Parameters.

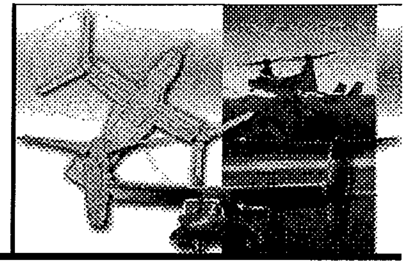
✔ Design Controllable MMH/FH Specification Requirements Adjusted To A Predicted Value At Fleet Maturity (60,000 Flight Hours).



V-22 OSPREY

DESIGNED FOR SUPPORTABILITY

Supportability Enhancements



Design Influence Tools - Testability

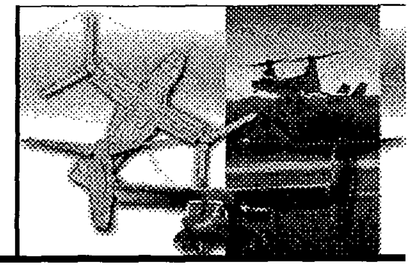
❸ Maximize Built In Test/On Board Diagnostics

- ✔ **Central Integrated Checkout (CIC) Monitors Avionics & Electronics Systems**
  - Power Up BIT
  - Pre-Flight Initiated BIT (IBIT)
  - Periodic BIT
  - Maintenance Initiated BIT (MBIT)

- ✔ **Components Are Monitored Through:**
  - Initiated Built In Test (IBIT)
  - Continuous Built In Test (BIT)

- ✔ **Vibration Structural Life & Engine Diagnostics Monitors**
  - Rotor Track And Balance
  - Engine Performance And Health Diagnostics
  - Structural Loads Monitored On Dynamic Components

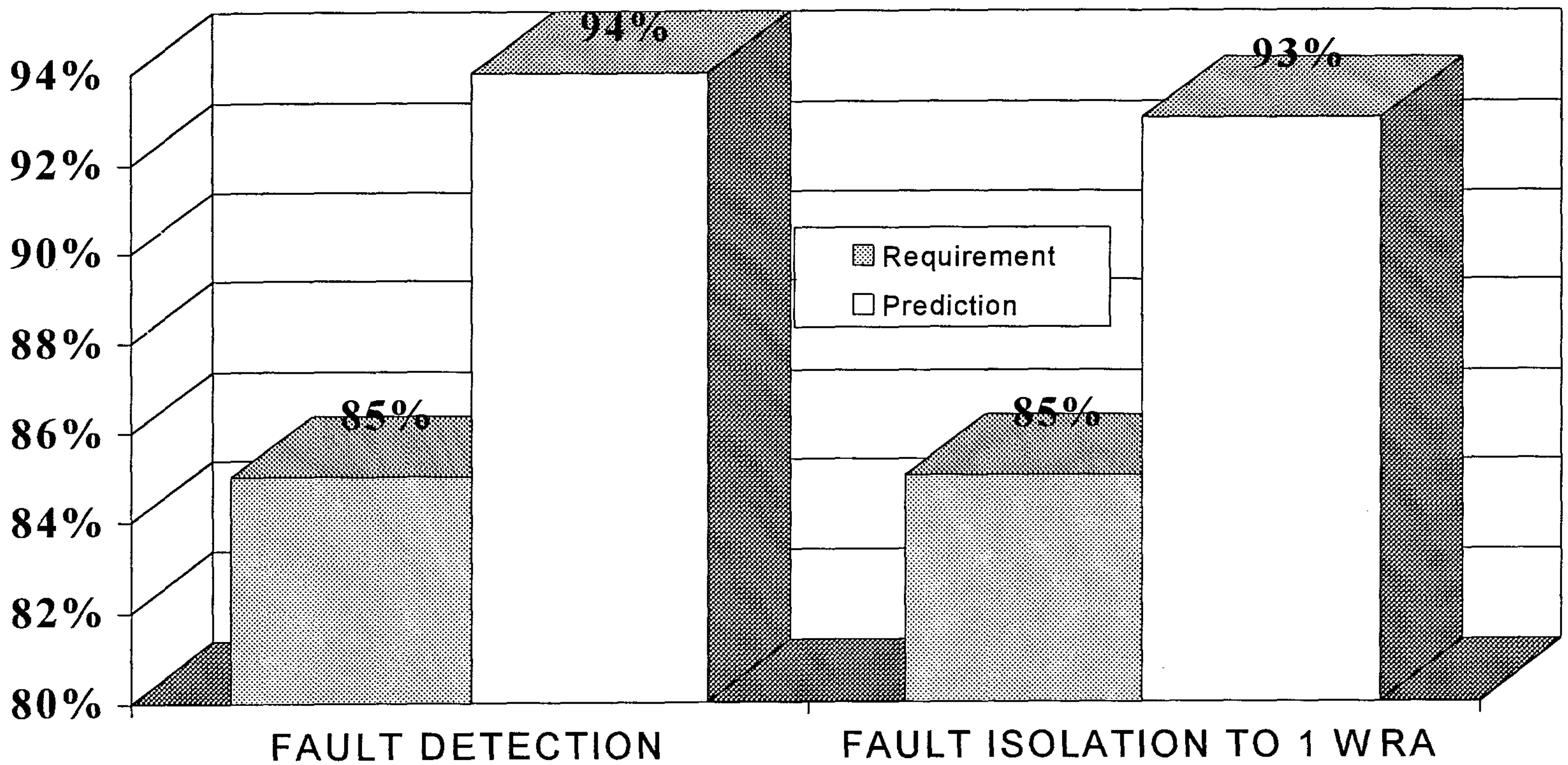
- ✔ **Reduces Reliance On Support/Test Equipment, Improves Mobility**
- ✔ **Reduces Fielding Costs**



Supportability Enhancements

Design Influence Tools - Testability

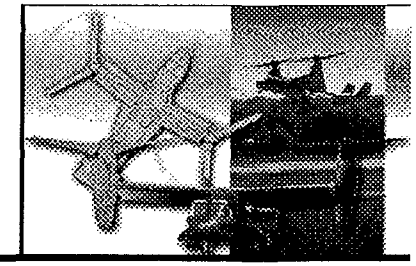
- Total Electronic/Electrical



V-22 OSPREY

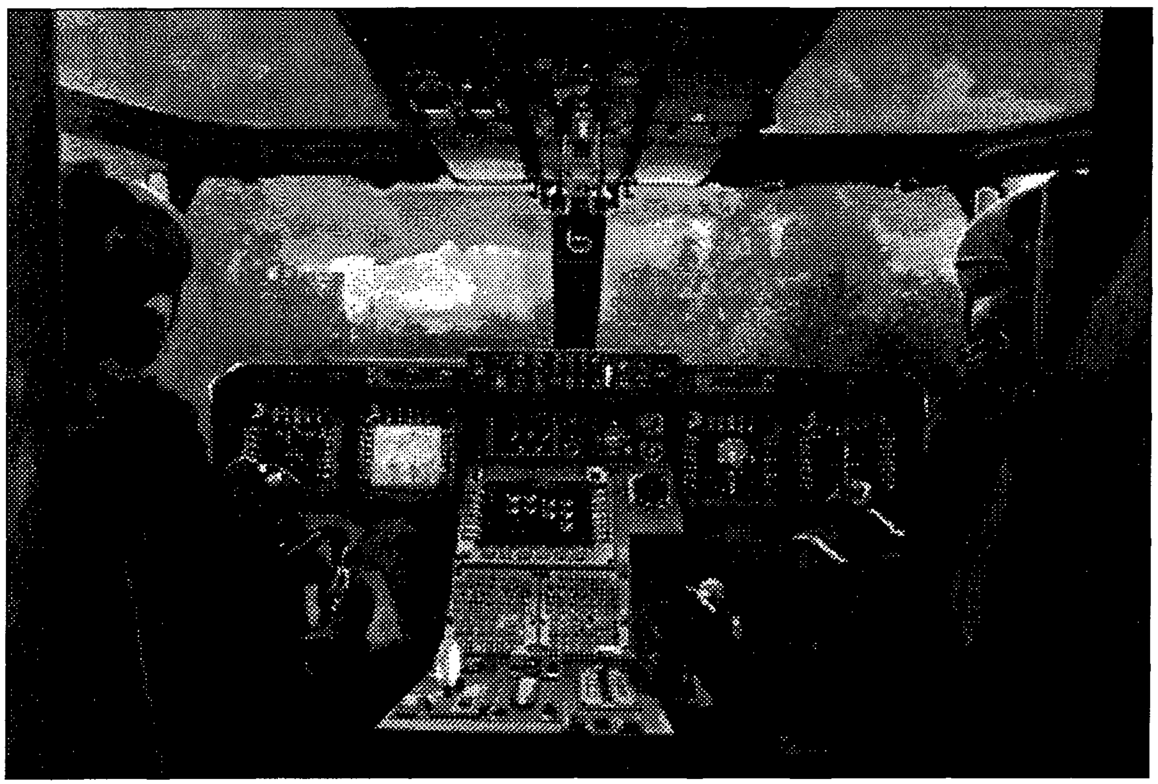
DESIGNED FOR SUPPORTABILITY

Supportability Enhancements



Design Influence Tools - Testability

- **Built-In-Test/Cockpit Management System**
  - Separation Of Operator And Maintainer Display Layers



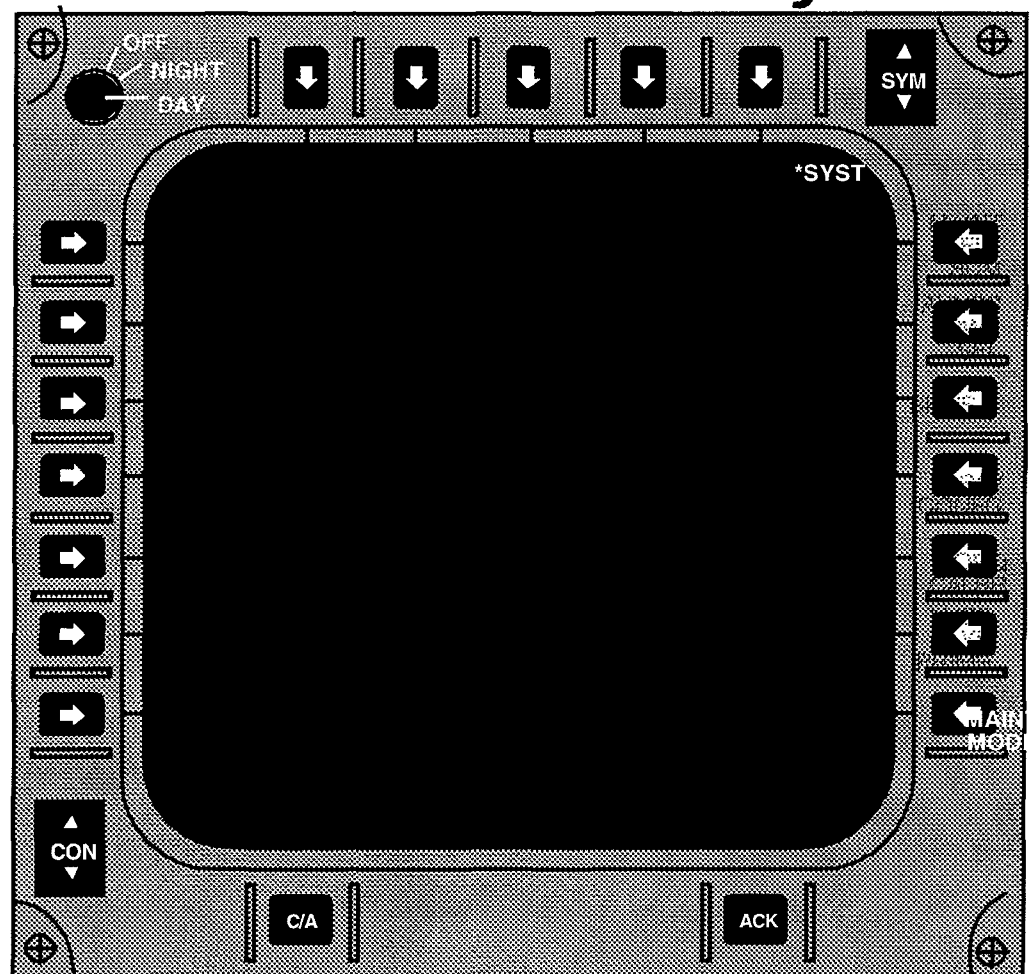
  - Developed Dedicated Maintainer Status Layers For Conducting Maintenance/Troubleshooting And System Calibrations

Supportability Enhancements

Design Influence Tools - Testability

- **Built-In-Test/Cockpit Management System**
  - Maintainer Dedicated Display Pages Developed Through A Dedicated IPT
  - Maintainer/Customer Input Was Invaluable

Maintainer Control Layer



V-22 OSPREY
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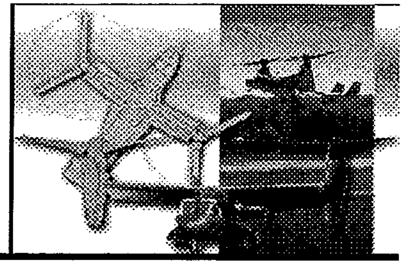
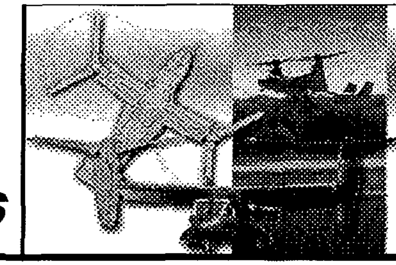
Supportability Enhancements



Design Influence Tools - Maintainability

❹ **Increase Reliability, Maintainability, and Accessibility For Maintenance And Servicing**

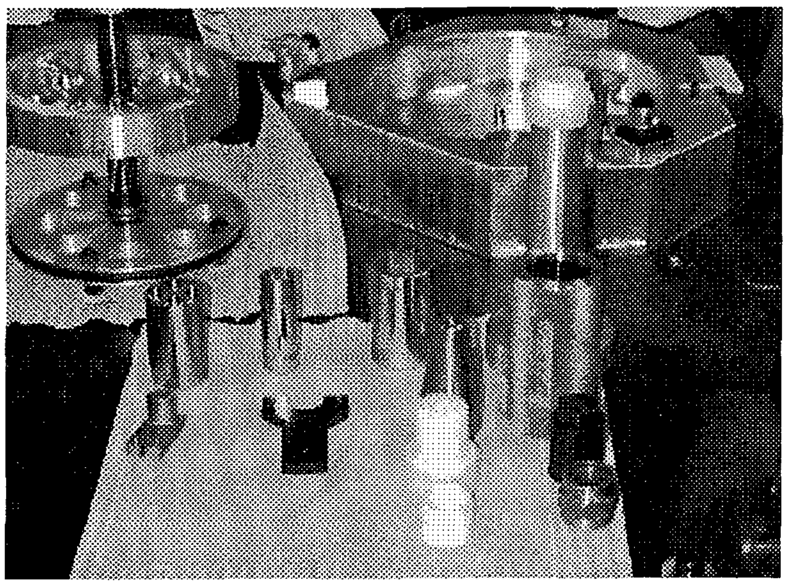
- **Supplier Maintainability/Testability Demonstrations**
  - Hardware/Software Fixes Implemented To Meet Mean Time To Repair (MTTR) & Fault Detection/Isolation Requirements
  - Production Configuration Hardware/Software Utilized

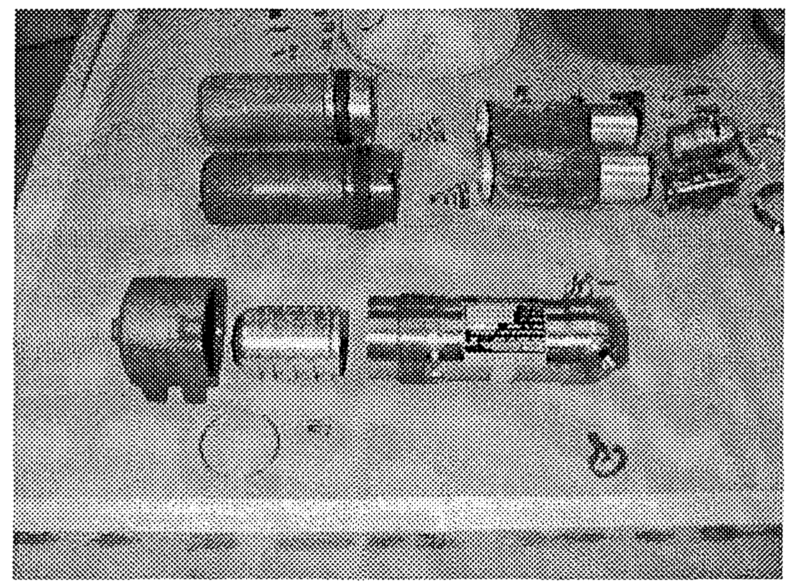


Supportability Enhancements

Design Influence Tools - Maintainability

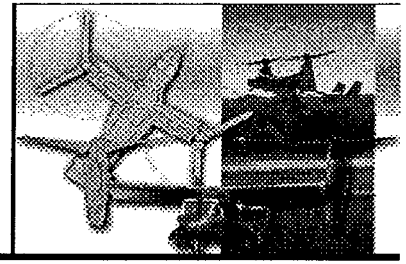
Supplier Maintainability/Testability Demonstrations





- Complete Teardown/Fault Insertion
  - Used By Suppliers To Validate "I" Level Pubs
  - Generating Additional Database For Future Product Improvements

Supportability Enhancements

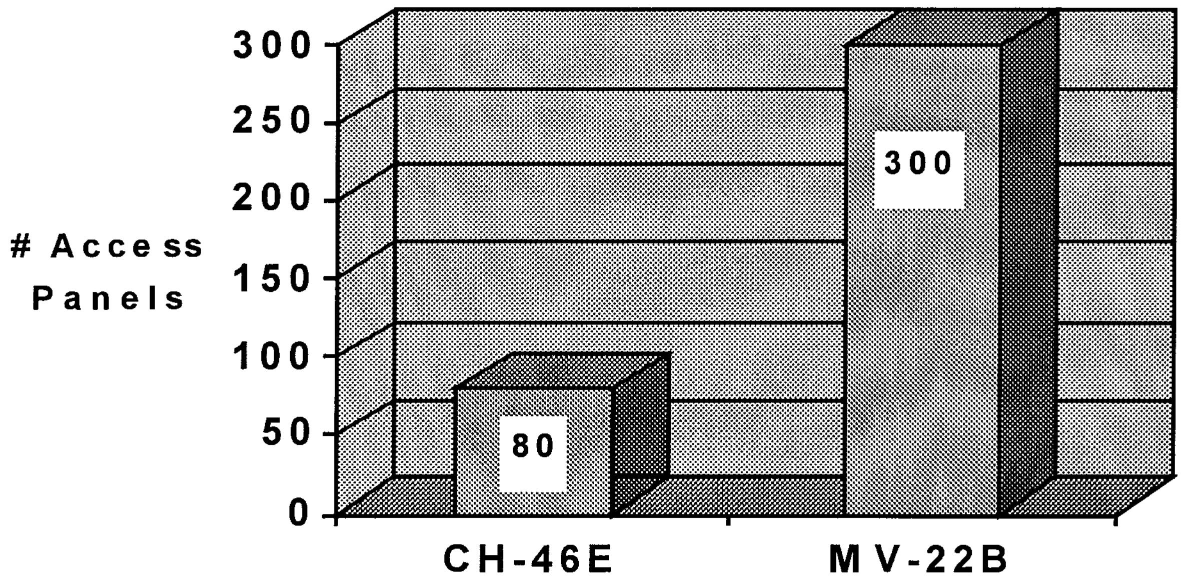


Design Influence Tools - Maintainability

Accessibility Evaluations

- Electronic/Hard Mock-Ups, Fit-Checks, And Design Trade-Offs
- Divergent Requirements For Weight & Accessibility Overcome

Access Panel Comparison



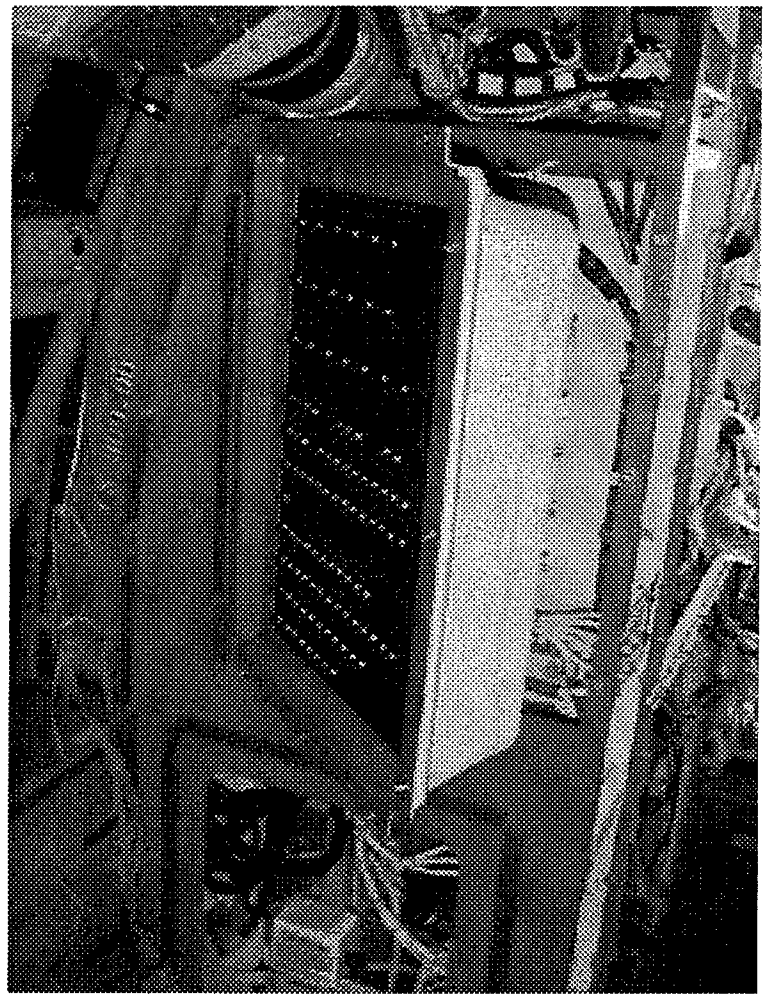
Design Influence Tools - Maintainability

Examples Of Maintainability Features

Circuit Breaker Panels

- Hinged Panel Assembly
  - Allows Ready Access to both CBs and Components Located Behind the Panel

Circuit Breaker Panel



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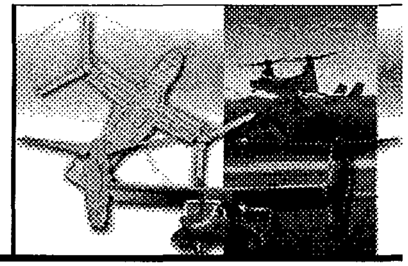


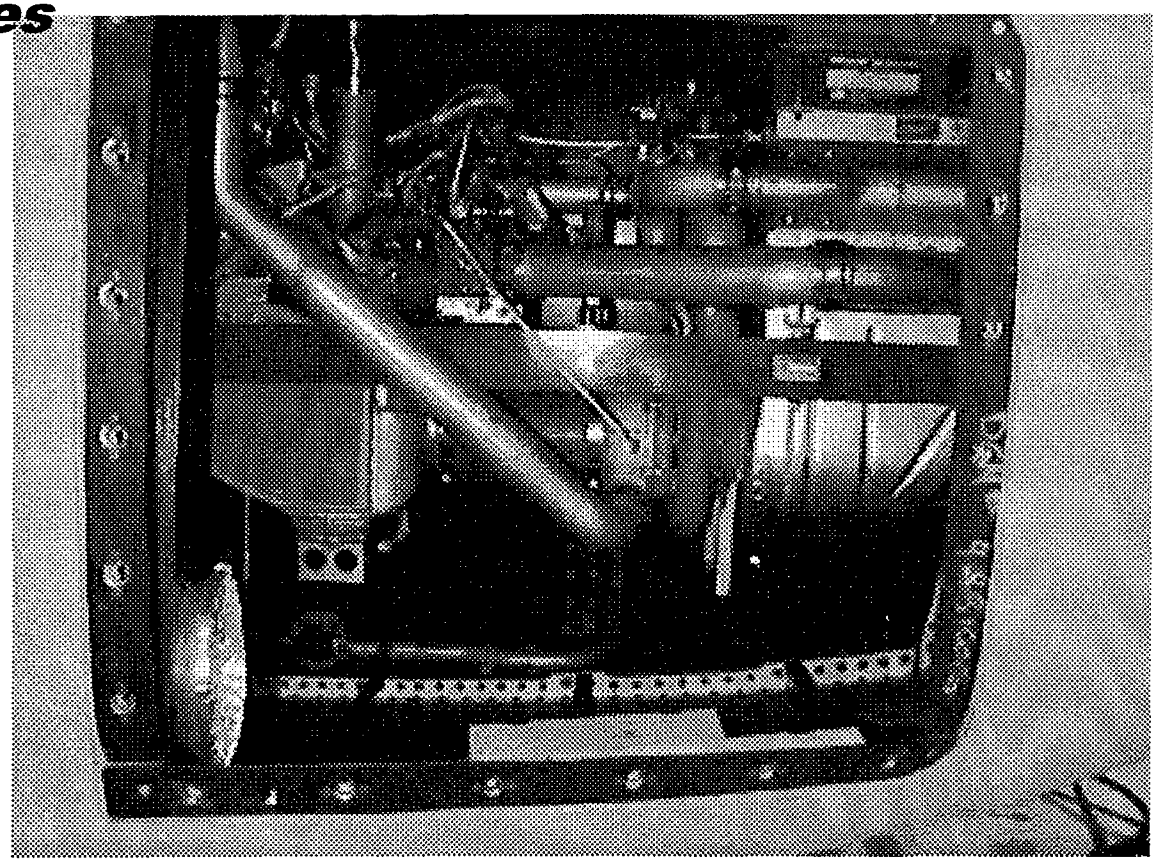
Supportability Enhancements

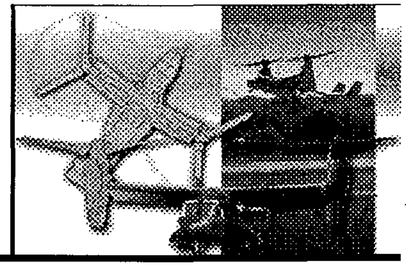
Design Influence Tools - Maintainability

Examples Of Maintainability Features

- Additional Panels Added To EMD Aircraft Based On Required Maintenance Actions:
  - Lower Door Facilitates Access to Components Mounted on the Assembly
  - Upper Door Allows for Removal of Entire Assembly

Environmental Control Unit





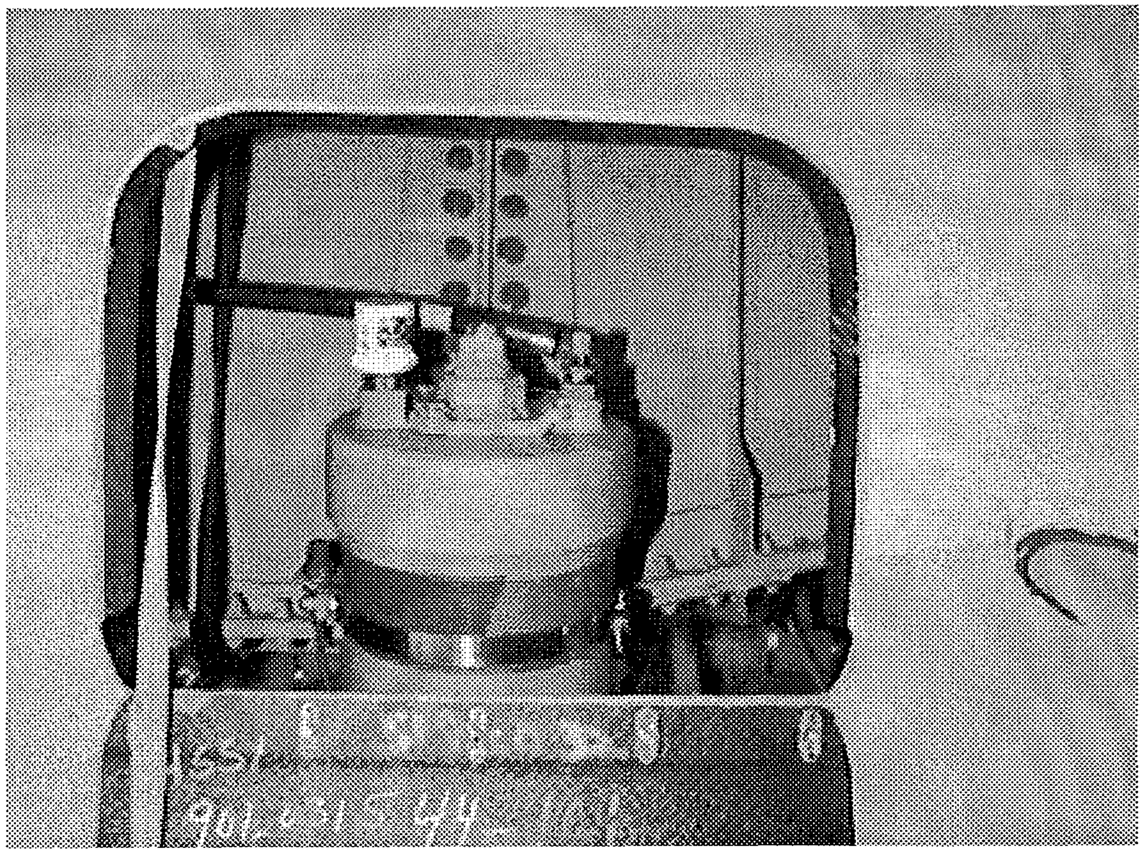
Supportability Enhancements

Design Influence Tools - Maintainability

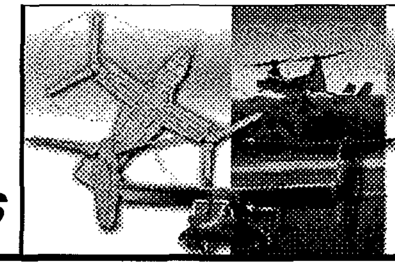
Examples Of Maintainability Features

- **Quick Release Servicing Door**
  - Size and Location Defined Concurrently by Maintainability and Design IPTs

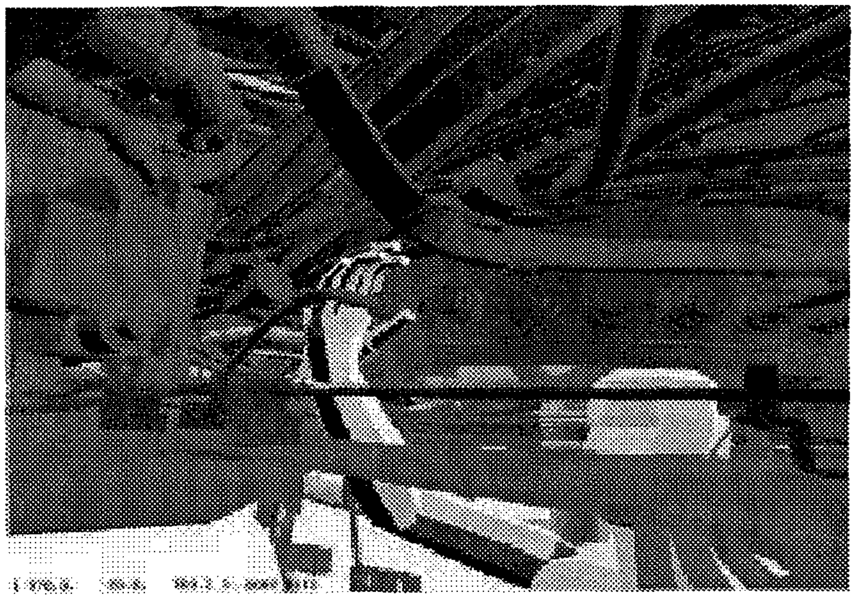
MLG Servicing Port



Supportability Enhancements

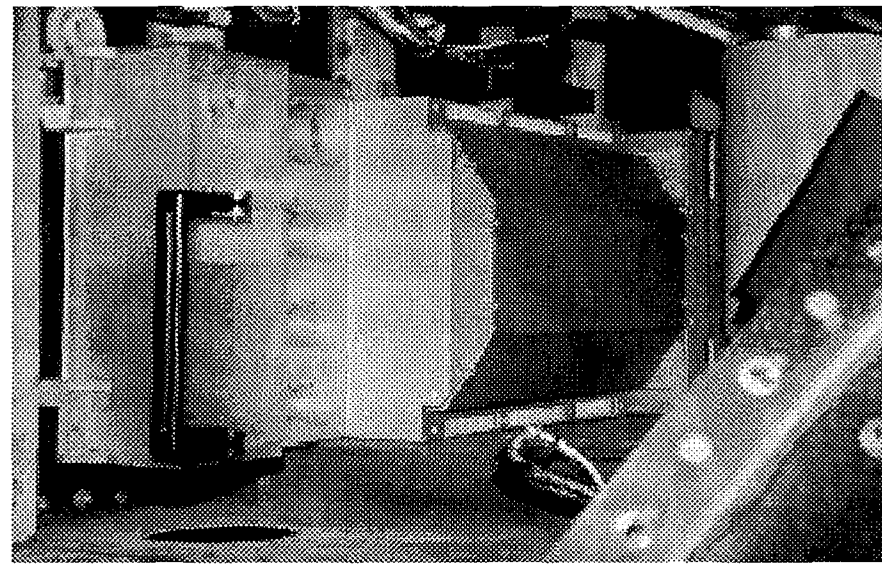


Design Influence Tools - Maintainability



Fly-thru human model

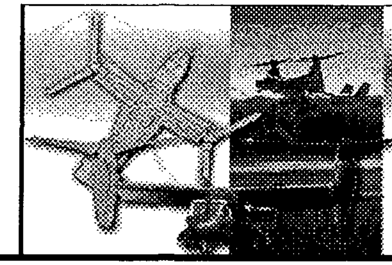
- CATIA/FLY-THRU: Allowed for maintenance envelope and solid human models simulations



Radar interface unit stereolithography mock-up

- MOCK-UPs: Component and systems evaluations conducted using actual hardware, stereolithograpic hardware, and physical mock-ups.

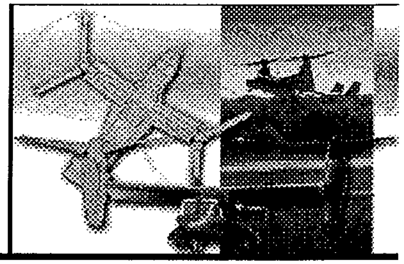
Supportability Enhancements



Design Influence Tools - Reliability

- **Reliability Development Testing (RDT)**
  - Implements Hardware Fixes Prior To Fleet Introduction
  -
- **RDT *Welcomes* Failures So They Can Be Designed Out Prior To Final Design Of The Equipment**
- **V-22 RDT Is One Of The Largest DoD Program Levied On A Major Weapon System**
-

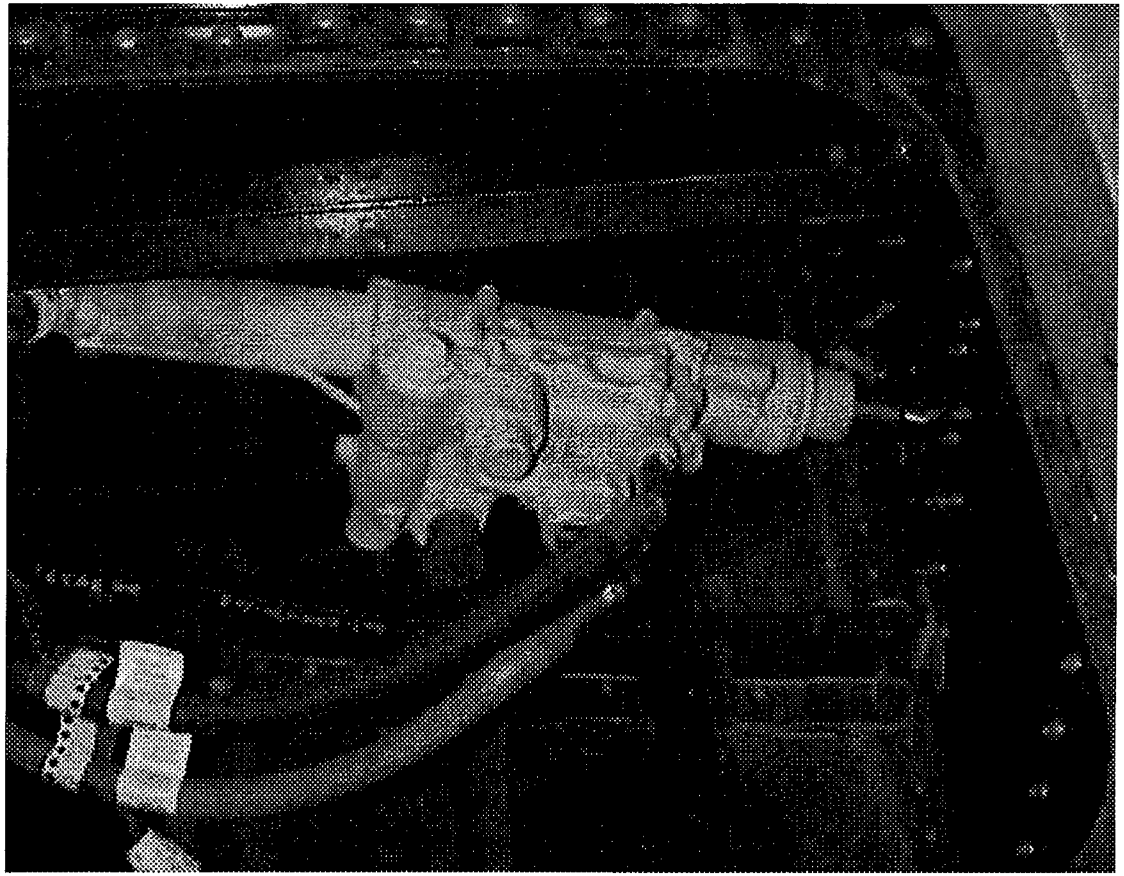
Supportability Enhancements



Design Influence Tools - Reliability

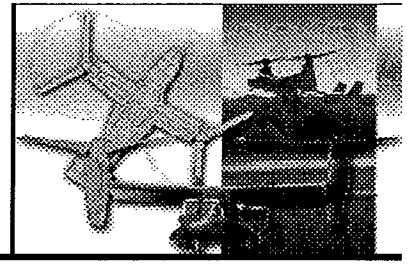
- **Reliability Critical Items Will Have Accumulated Over 100,000 Operating Hours Prior To Fleet Introduction**
- **86 Reliability Critical Items To Be Operated Under Vibration And Temperature Environments Simulating Field Conditions**

Reliability Development Testing



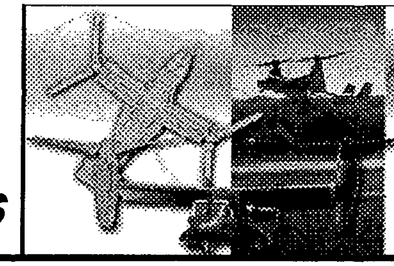
RDT Actuator under test

Supportability Enhancements



❺ Reduced Scheduled Maintenance and Repair Actions

- **Preflight (NATOPS) - Prior to 1st flight of the day**
  - Airline style walk around, check for security, obvious damage, removed covers,
- **Turnaround (RCM) - Between flights of 3 flight hours**
  - Verify integrity of aircraft, proper servicing, detect degradation
- **Postflight (NATOPS) - After last flight of the day**
  - Airline style walk around, similar to preflight. Use GRDP to check fluid levels
- **35 Hr (RCM) - After 35 flight hours**
  - General visual inspections to detect damage, defects or degradation

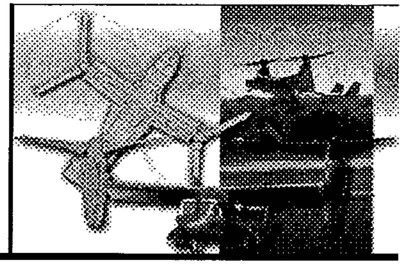


Supportability Enhancements

⑤ Reduced Scheduled Maintenance and Repair Actions

- 105 Hr (RCM)
  - Perform every third 35 hour inspection
- 210 Hr Phase (RCM) - Start of four cycle phased inspection
  - Detailed inspection, segmented in 4 x 210 flight hour elements

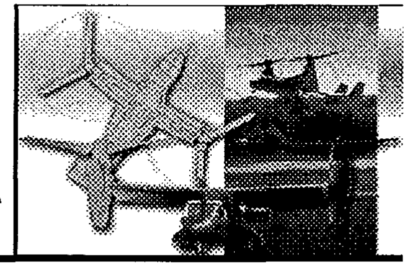
Supportability Enhancements



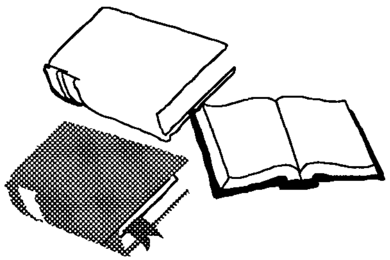
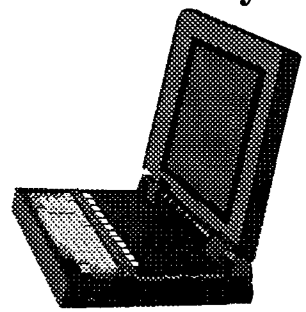
⑥ **Develop And Implement An On-Condition Maintenance Philosophy**

- ✓ **Challenge The Traditional Maintenance, Servicing, Testing And Inspection Philosophies, (No Daily, Reduced Fuel & Oil Sampling Intervals)**
- ✓ **On Board Systems And Component Monitoring Allow Health Trending**
- ✓ **On Board Memory Inspect Capability Reduces Fault Isolation, Testing & Troubleshooting Efforts**
- ✓ **Components Are Removed For Cause And Not For Scheduled Re-Work. There Are No TBOs, No Finite Life.**

Supportability Enhancements



❼ Develop (Level IV) Interactive Electronic Technical Manuals (IETMs)

Yesterday		V-22 Today
		
Maintenance Manuals	**OR**	**Small Lap-Top Computer**

Today's Problem

Shrinking Budgets

High Maintenance Costs Driven By False Repairs

Increasing Paper Manual Costs

CND Malfunction Scenarios Consume
- **Data**
- **Time and Money**

IETM Advantages

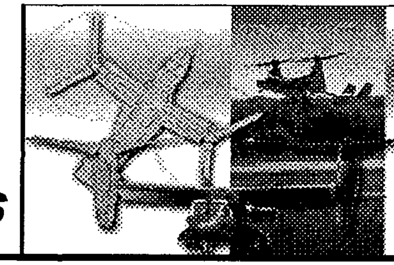
Increase in System Availability

Decrease in Maintenance Downtime

Decrease in Time to Obtain Support Data

Increase in Accuracy and Completeness of Data

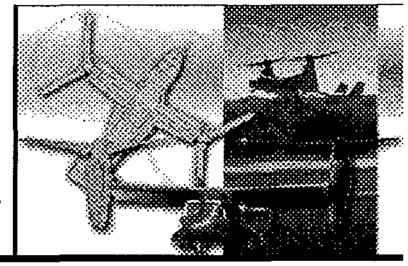
Reduced Maintenance Costs



Supportability Enhancements

❼ Develop (Level IV) Interactive Electronic Technical Manuals (IETMs)

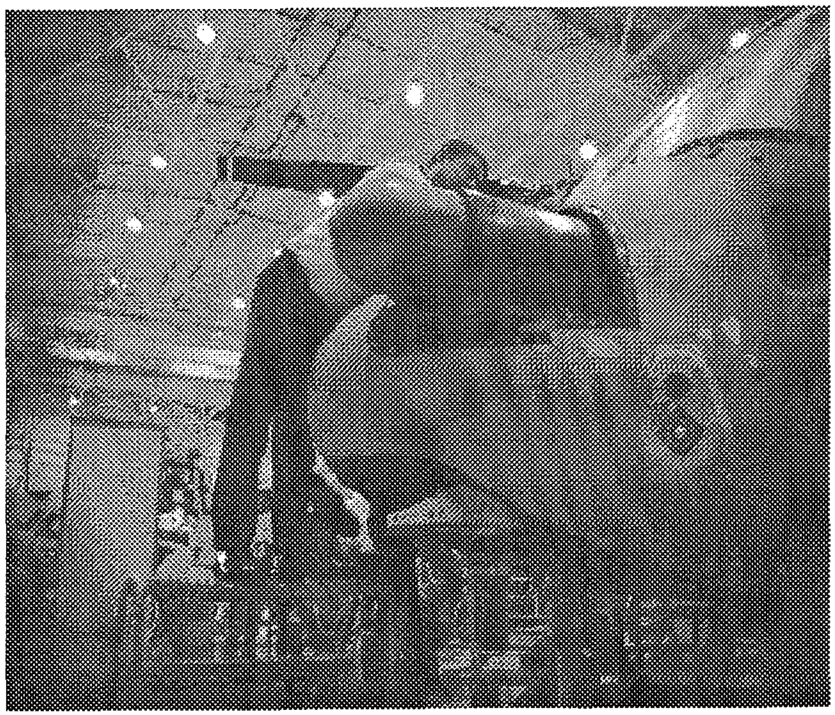
- ✔ The Bell-Boeing V-22 Publication Team developed Interactive Electronic Technical Manuals (IETMs) for the MV-22. The IETM for the V-22 program is a Class 4, Hierarchically Structured IETM.
- ✔
- ✔ A Class 4 IETM is defined by the MIL-M-87268 implementation guide as an "Interactive Electronic Display of Technical Information specifically authored into, and maintained in, a non-redundant relational or object-oriented data base.



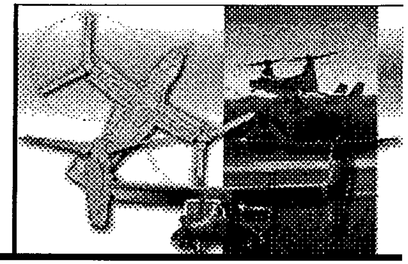
Supportability Enhancements

❽ Minimize Support Equipment Requirements

- **Use existing organic maintenance equipment and standard aviation tools almost exclusively.**
  - **At 198 total pieces of Organizational level support equipment, the V-22 requires the least amount of any modern rotary wing platform.**



- **Built-in access and maintenance doors are provided for easy access to fuselage, engine and nacelle systems/ components when conducting routine inspections and maintenance.**

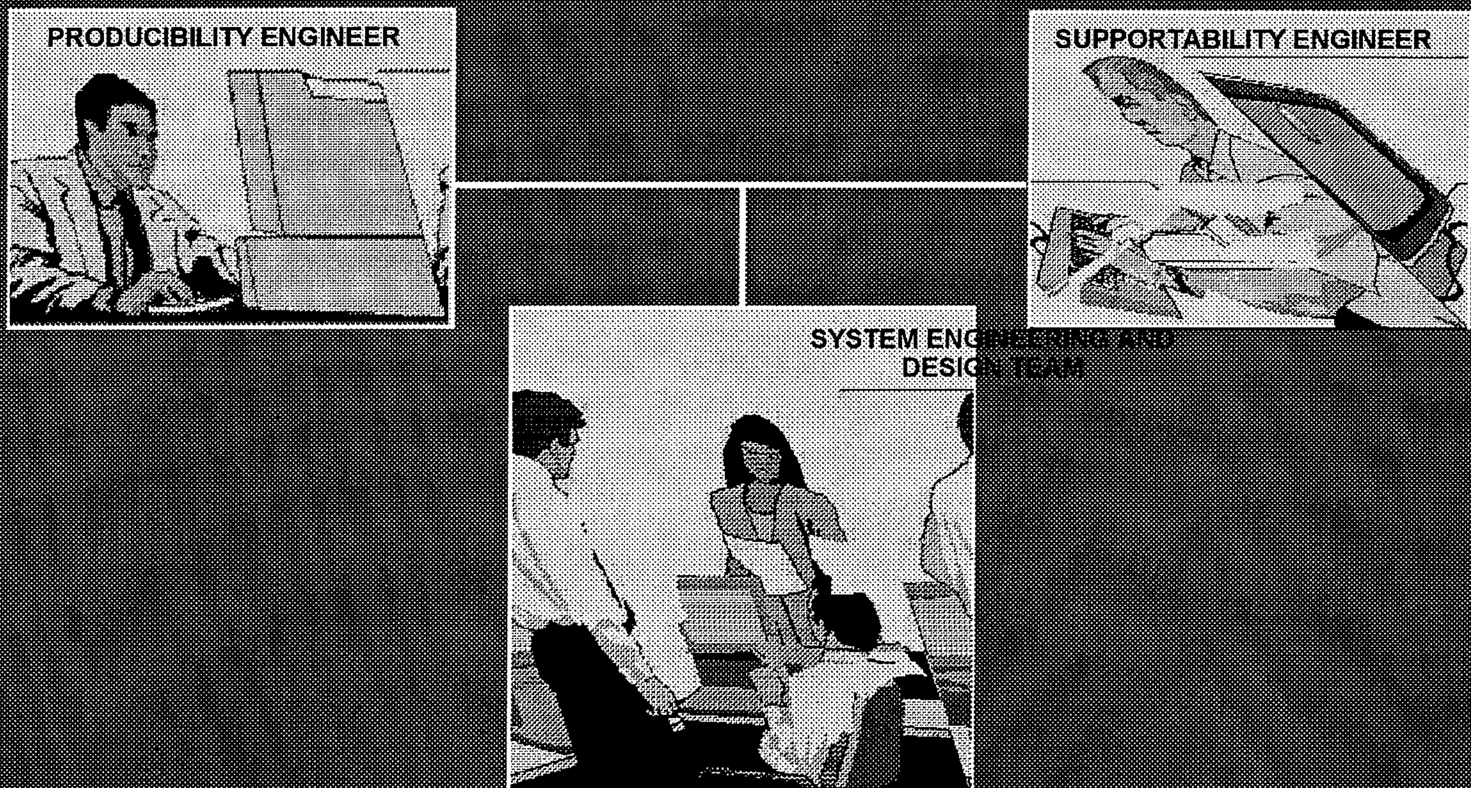


SUMMARY

- ✓ Maintenance & Support Parameters Are Optimized
- ✓ Scheduled Maintenance And Repair Are Reduced
- ✓ Scheduled Component Removal Is Minimized
- ✓ BIT & On Board Diagnostics Is In Place
- ✓ On-Condition Maintenance Philosophy Embraced
- ✓ IETM Will Be Fully Developed
- ✓ Reliability, Maintainability & Accessibility Has Been Optimized

TRW

Integrated Producibility and Supportability Requirements Analysis



Paul Blackwell NADEP-NI

W. Erich Hausner

Requirements Are ***Fundamental!***

- **Supportability *won't* happen if requirements are not**
  - substantive
  - timely
  - understood
  - feasible
  - traceable and testable
- ***"Critiquing the design"* is already too late!!**

POTENTIAL BENEFITS

TRW

CUSTOMER

- Rigorously identifies Producibility and Supportability cost drivers
- Tracks contractor's degree of Producibility and Supportability design progress
- Reduces risk by minimizing transition impact from production to support

CONTRACTOR

- Producibility/Supportability Engineering
  - Integrates Producibility and Supportability with Systems Engineering
  - Provides critical communication link with designer to achieve information "design fusion" and feedback to production and support IPTs
  - Promotes use of knowledge-based decision support
  - Accelerates proposals, ECPs, and Service Life Extension Programs (SLEPs)
- Design Engineering
  - Early requirement inputs stimulate innovation and design solutions
  - Enhances IPT's interactive functionality during product definition

AFFORDABLE READINESS

GUIDING PRINCIPLES (CAIV)

- *COST AND PERFORMANCE DYNAMICS MUST BE UNDERSTOOD:*
  - **PERFORMANCE IMPROVES OVERTIME. TECHNOLOGY TREND ANALYSIS IS NEEDED -- BOTH DOD & COMMERCIAL.**
  - *COST OF TECHNOLOGY IS REDUCED OVER TIME (MANUFACTURING PROCESSES MATURE, BUSINESS PRACTICES CHANGE). COST TREND ANALYSIS S NEEDED.*
- *TOOLSET MUST BE ADAPTIVE AND FLEXIBLE*
- *COST AND PERFORMANCE MUST BE LINKED:*
  - **COST IS INFLUENCED BY MULTIPLE PERFORMANCE PARAMETERS**
  - **DESIGN/IMPLEMENTATION STILL NEEDS TO BE ADDRESSED**
- **SYSTEM PERFORMANCE AND COST ARE TYPICALLY DRIVEN BY A FEW SUBSYSTEMS AND COMPONENTS**
- **SUBSYSTEM SOLUTIONS CANNOT BE DETERMINED IN ISOLATION**

THE CONCURRENT ENGINEERING ENVIRONMENT

PRODUCIBILITY
SUPPORTABILITY

- Integrated Information
- Enhanced IPT Interaction
- Uniform Metrics
- JCALS Potential

Our Contract with PMA 209 Implemented Affordable Readiness and Flexible Sustainment

TRW

Two goals dominate our supportability strategy

- Reduced cost of ownership across all elements of the life cycle
- Innovative support solutions that significantly reduce the O&S cost burden

Our principle focus: ***Affordable Readiness and Flexible Sustainment***

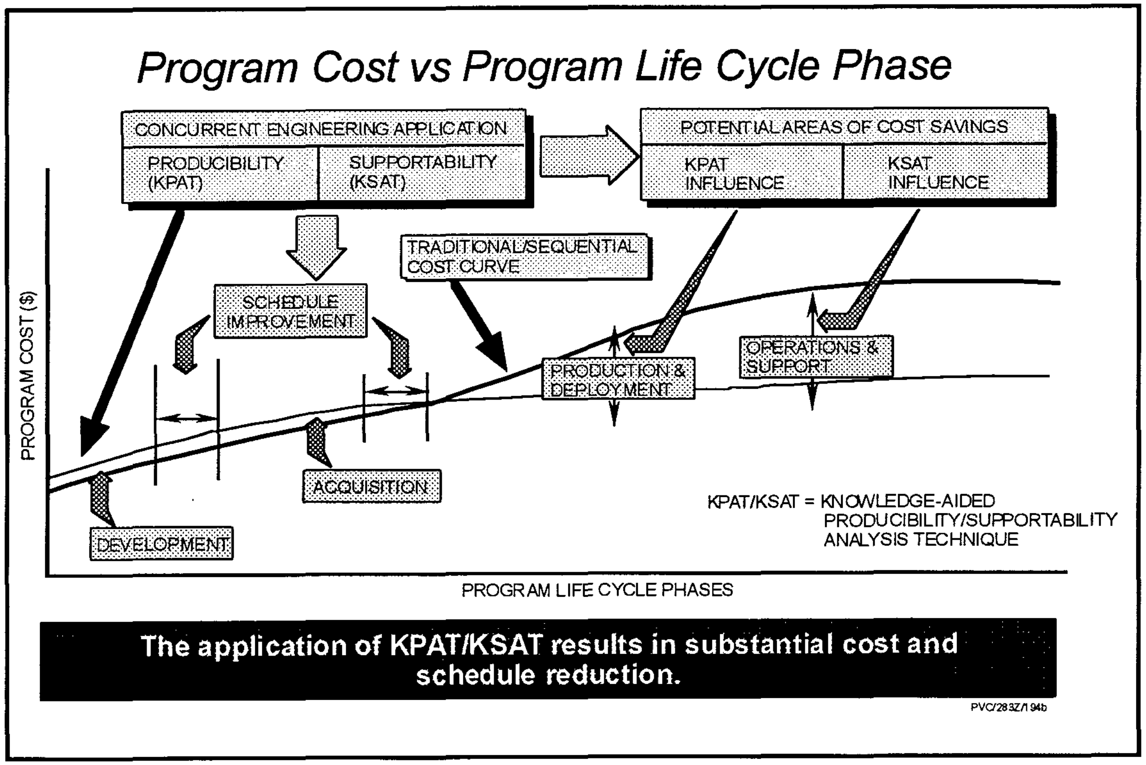
TRW's concept of total cost relationships provides a venue for advances in supportability engineering

Use best processes and related toolsets to reduce production and support event drivers and seek the "system " solution

KPAT/KSAT provides the unique capability to integrate producibility and supportability

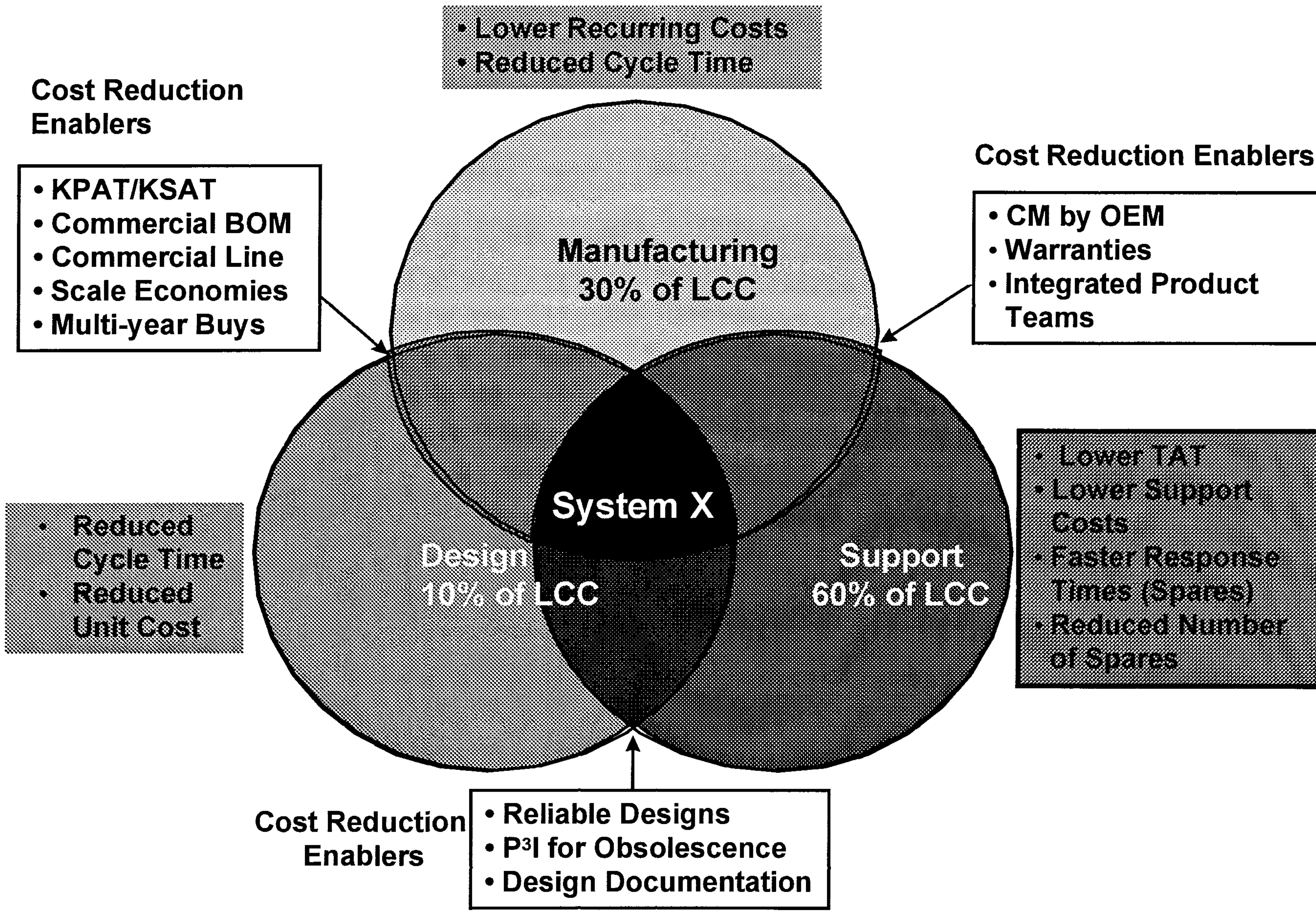
Embedded in KPAT/KSAT are metrics to evaluate relationships (Performance/design/cost)

NAVAL AVIATION SYSTEMS TEAM



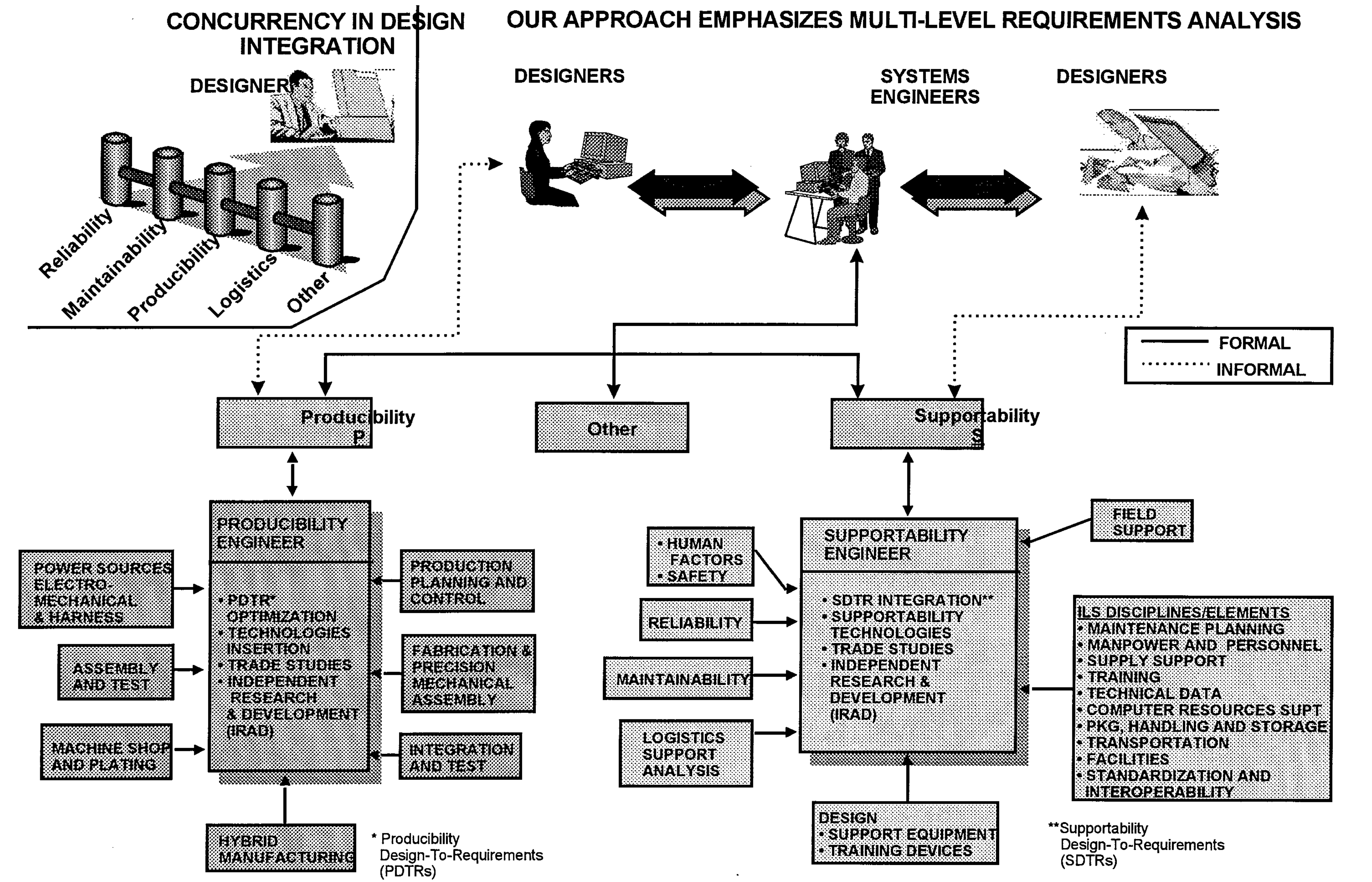
TRW's Approach to Supportability Emphasizes Information Integration to Reduce Cost of Ownership

TRW



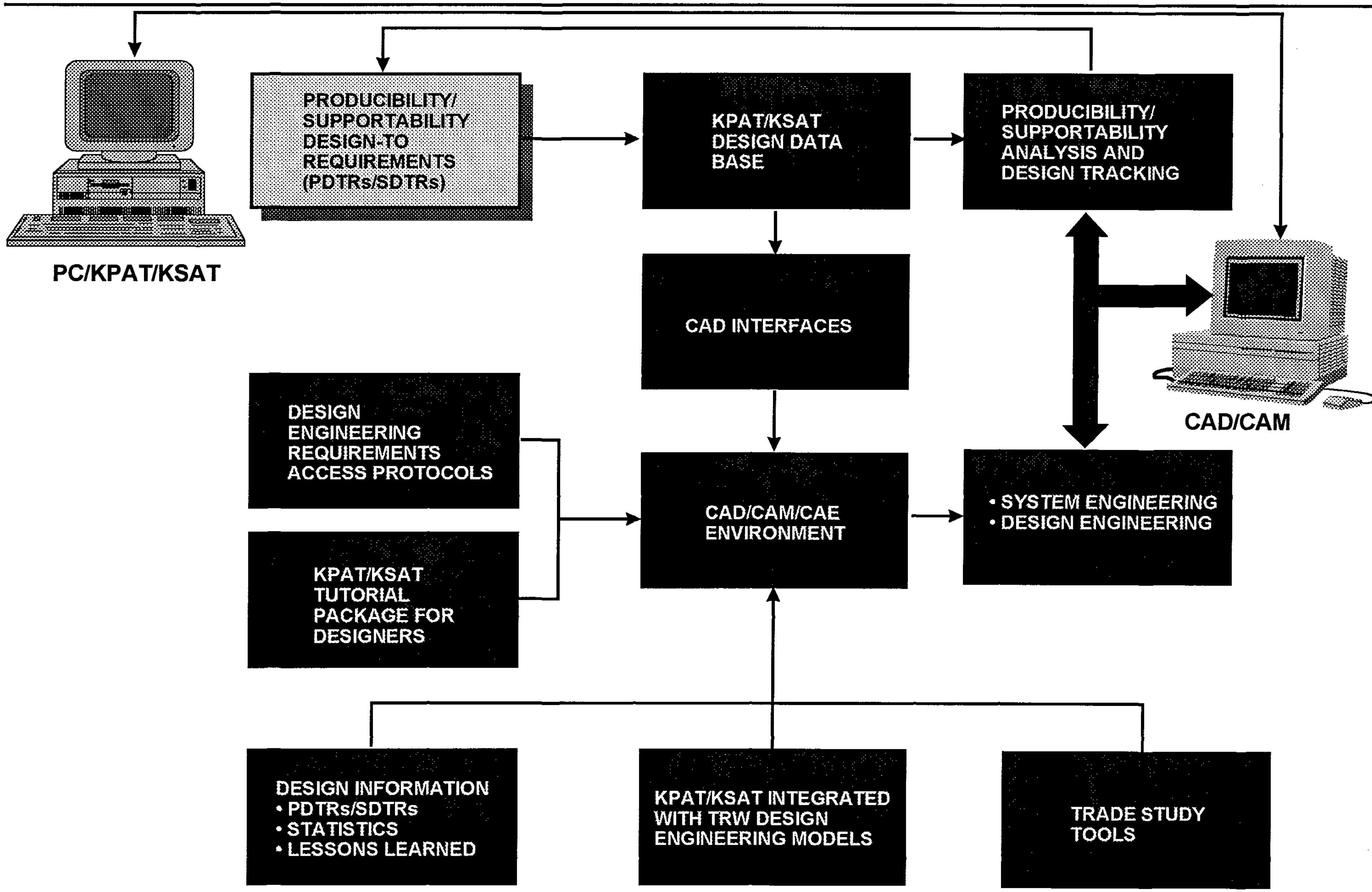
TRW

Concurrent Engineering (CE) Approaches

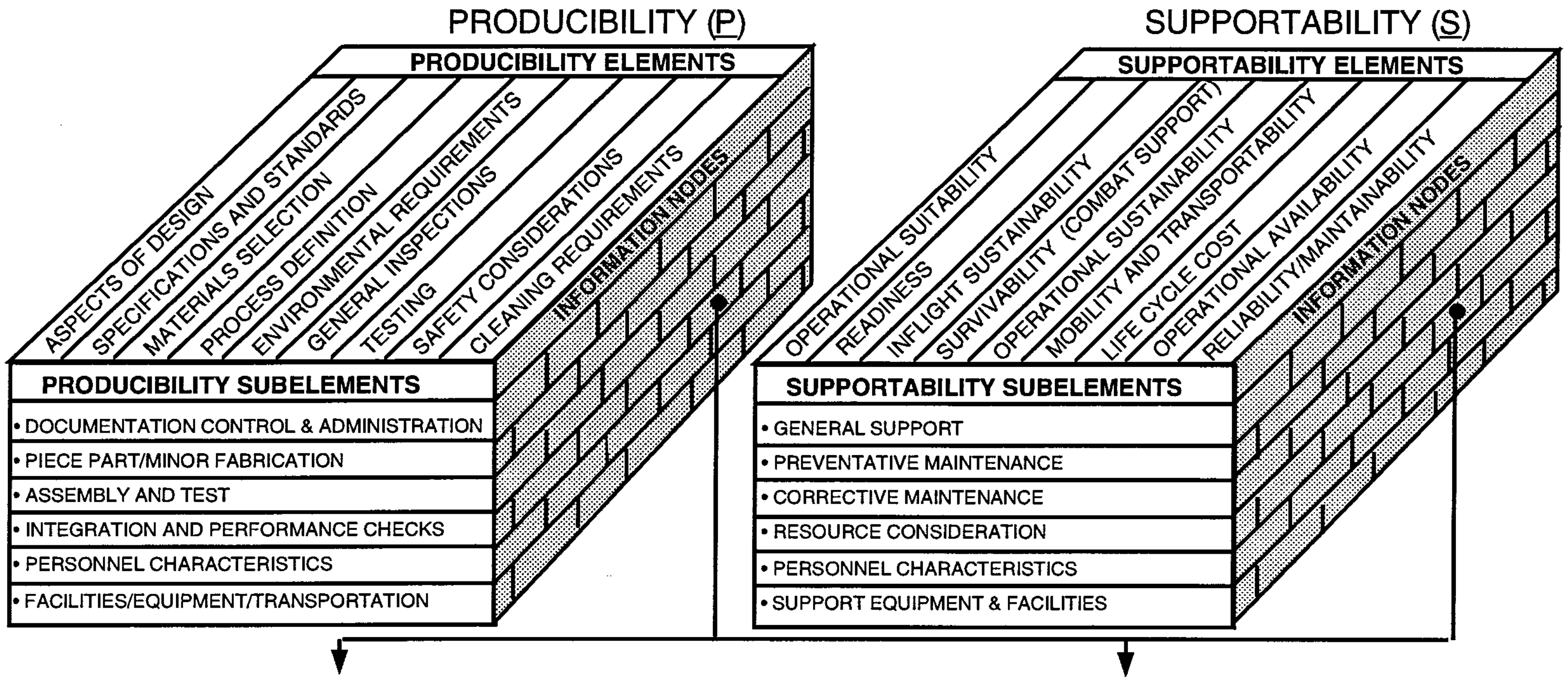


TRW

KPAT/KSAT Provides Outputs to CAD as Producibility/ Supportability Design-to Requirements (PDTRs/SDTRs)



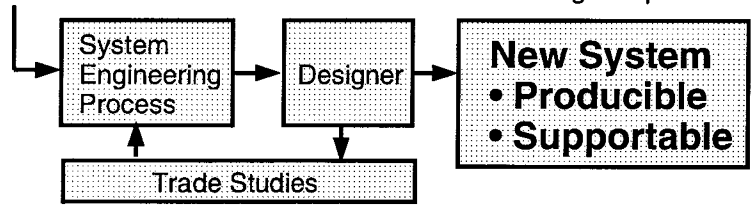
Lessons Learned And Design-to Requirements Information Shells



Producibility and Supportability Information Nodes/Cells
- Basis for design-to requirements
- Provide automated information management
  - Access
  - Retrieval
  - Use
  - Cell division/multiple applications
  - Traceability
  - Data base management
  - Artificial intelligence information clusters

Design-to Data Base

Cell Characteristics	Index	Requirements
• Producibility unique	⇒ AL	Film, metalized
• Supportability unique	⇒ 38	Service center
• Common/shared	⇒ 37	Mounting and positioning



Information management, knowledge capture, and a dynamic systems engineering environment result in producible and supportable products.

PVC/283Z/194a

PRODUCIBILITY ENGINEERING

Algorithms Define Producibility (P) Design Characteristics

TRW

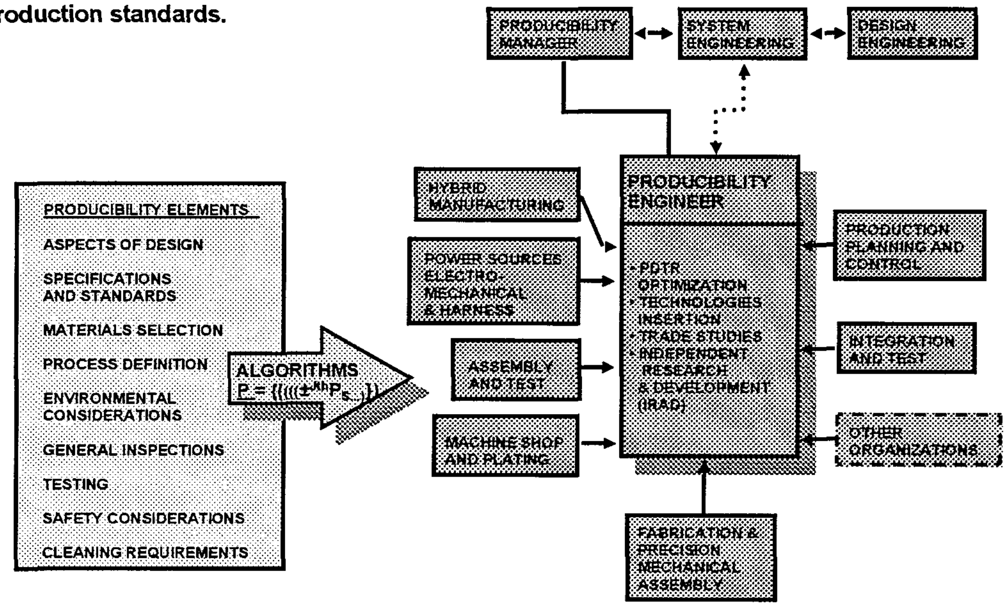
$\underline{P}$ = Producibility. Producibility is a metric with respect to production event frequency, duration, and cost that reflects composite characteristics of the manufactured system (project), to meet specified quantity, schedule and production standards.

$\underline{P} = F(f, d, c)$

Where:
f = manufacturing event frequency
d = manufacturing event duration
c = manufacturing event cost

$\underline{P}$ is at its optimum for the project when $\underline{P}$ approaches "0" with respect to f, d, and c,
or $\underline{P}_{OPT} = \underline{P}_{BASELINE} >>> \underline{P}_{PROJECT}$

$$\underline{P}(f, d, c)_{OPT} = \Big\{ \big[(\Sigma_1^{jTH} K_b \pm ADJ) * \Sigma_1^6 SE(WT_b) * \Sigma_1^9 E(WT_b)\big]_f$$
$$\big[(\Sigma_1^{jTH} K_b \pm ADJ) * \Sigma_1^6 SE(WT_b) * \Sigma_1^9 E(WT_b)\big]_d$$
$$\big[(\Sigma_1^{jTH} K_b \pm ADJ) * \Sigma_1^6 SE(WT_b) * \Sigma_1^9 E(WT_b)\big]_c \Big\}_{BASELINE}$$
$$(>>>)$$
$$\Big\{ \big[(\Sigma_1^{jTH} M_b \pm \Sigma_1^{nTH_L}) * \Sigma_1^6 SE(WT_m) * \Sigma_1^9 E(WT_m)\big]_f$$
$$\big[(\Sigma_1^{jTH} M_b \pm \Sigma_1^{nTH_L}) * \Sigma_1^6 SE(WT_m) * \Sigma_1^9 E(WT_m)\big]_d$$
$$\big[(\Sigma_1^{jTH} M_b \pm \Sigma_1^{nTH_L}) * \Sigma_1^6 SE(WT_m) * \Sigma_1^9 E(WT_m)\big]_c \Big\}_{PROJECT}$$



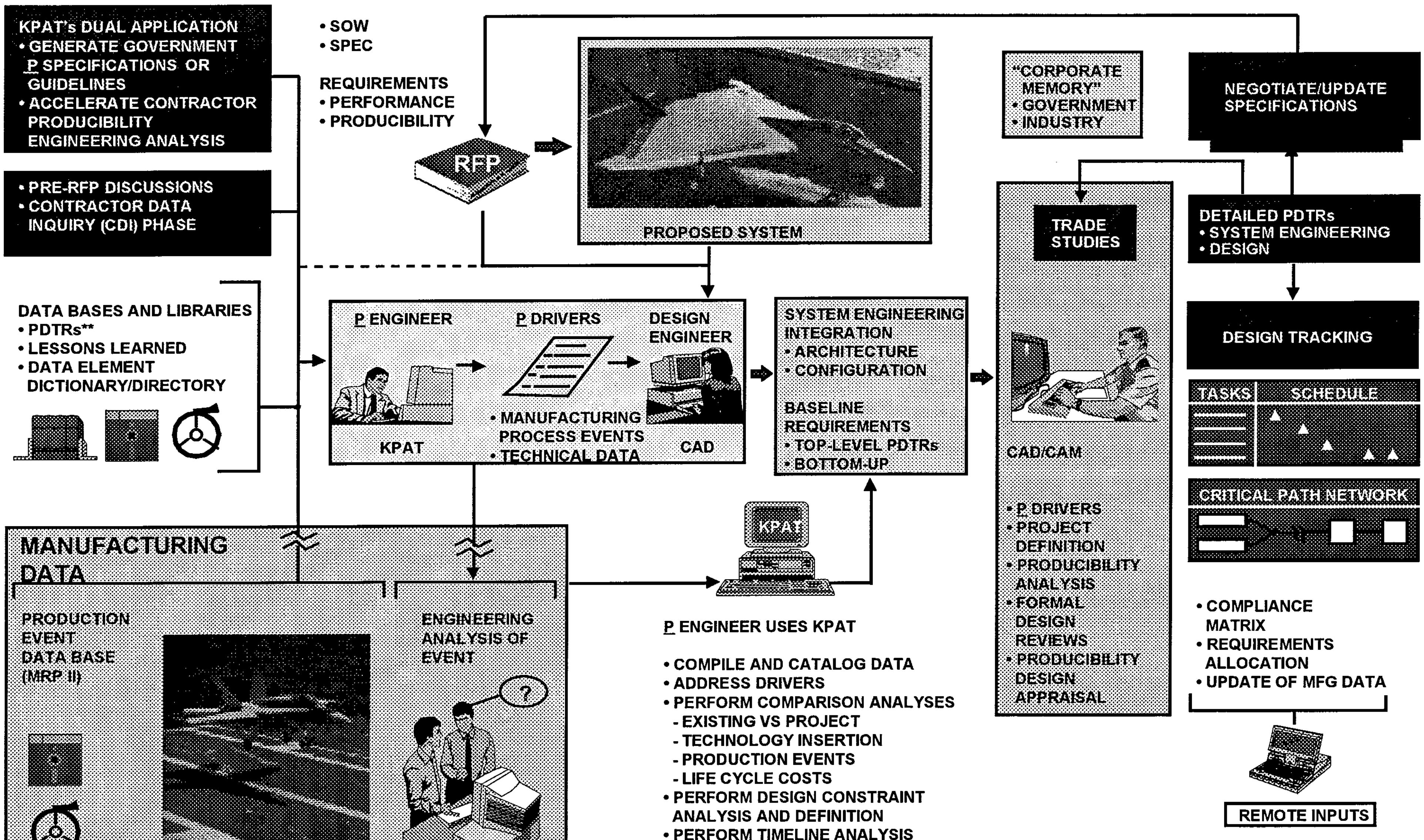
ADJ = Correction of baseline value or historical data
B or b = Baseline, existing or predecessor system
E = Producibility elements - major
1) Aspects of design
2) Specifications and standards
3) Materials selection
4) Processes definition
5) Environmental requirements
6) General inspections
7) Testing
8) Safety considerations
9) Cleaning requirements
ECP = Engineering change proposal

jTH = Selection range of baseline parameter values
K = Parameter, reflecting historical data
K_b = Parameter baseline from comparative, historical WBSs
L = Unique set of PDTRs analyses that address baseline system and generate project requirements
M or m = Project, new system or major ECP
nTH = Selection range of PDTRs that operate (+ or -) on the jTH set of baseline values of f, d, or c.
$\underline{P}(f, d, c)_{OPT}$ = Producibility at optimum state when support events approach "0" (minima)
PDTR = Producibility design-to requirements

SE = Producibility element - subordinate
1) Documentation control and administration
2) Piece part/minor fabrication
3) Assembly and test
4) Integration and performance checks
5) Personnel characteristics
6) Facilities/equipment/transportation
WT_b = Weighted or relative importance of elements - baseline
WT_m = Weighted or relative importance of elements - project
WBS = Work breakdown structure reflects system data definition for historical data collection or for new systems

The KPAT* Augments Producibility (P) Design Analysis

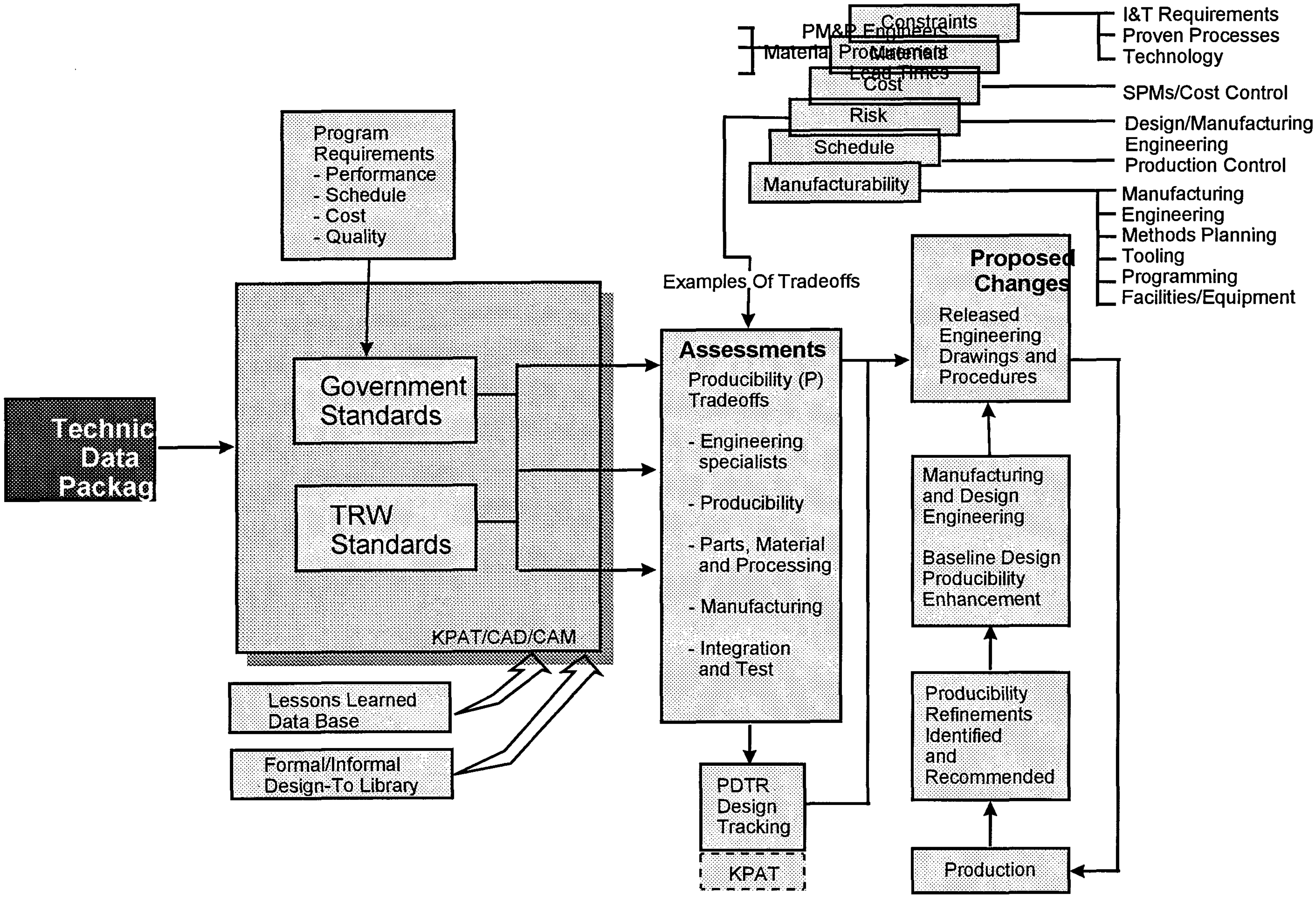
TRW



* KNOWLEDGE-AIDED PRODUCIBILITY ANALYSIS TECHNIQUE (KPAT)
** PRODUCIBILITY DESIGN TO REQUIREMENTS (PDTRs)

Beyond Traditional DFA/DFM Tools is KPAT WhichProvides CAD-Linked PDTRs to Design

TRW



TRW

Producibility Assessment Process

Use Knowledge-Aided Producibility Analysis Technique (KPAT) to bench-mark Producibility Characteristics

- Review existing designs to optimize for producibility
- Producibility Design-To-Requirements (PDTRs) can provide comparison basis
- PDTRs serve as guidelines during the Technology Insertion Process to ensure technology does not proliferate producibility risks
- Integrate with KSAT to maximize producibility/supportability synergism

Augment with traditional DFM analysis (Boothroyd Dewhirst)

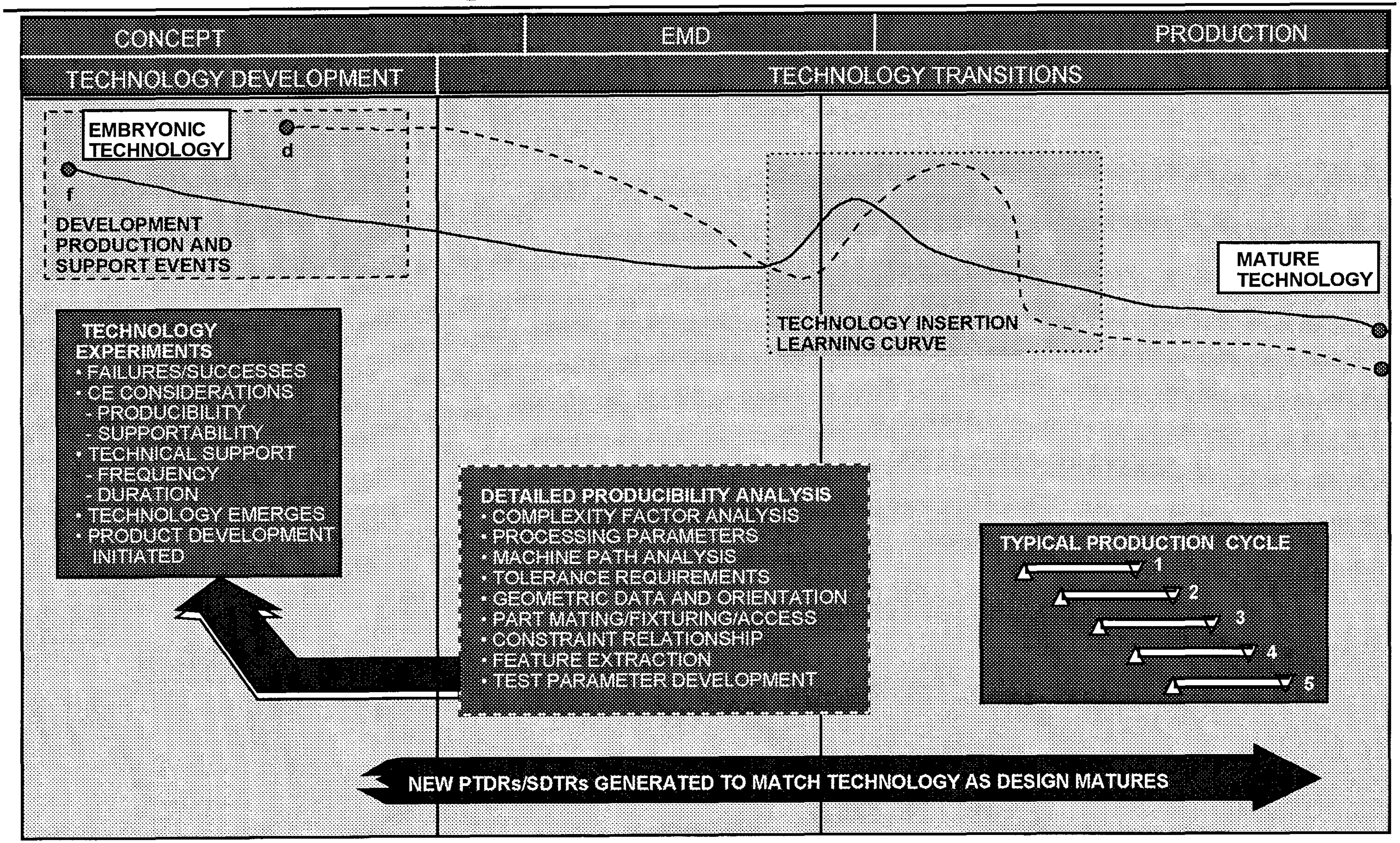
Simulate factory flow optimization after PDTR implementation to determine PDTR effectivenss

Incorporate PDTRs in the Technical Data Package

A disciplined, systematic approach enhances Producibility Implementation

TRW

Technology Development Provides Opportunity for Concurrent Engineering (CE) Influence

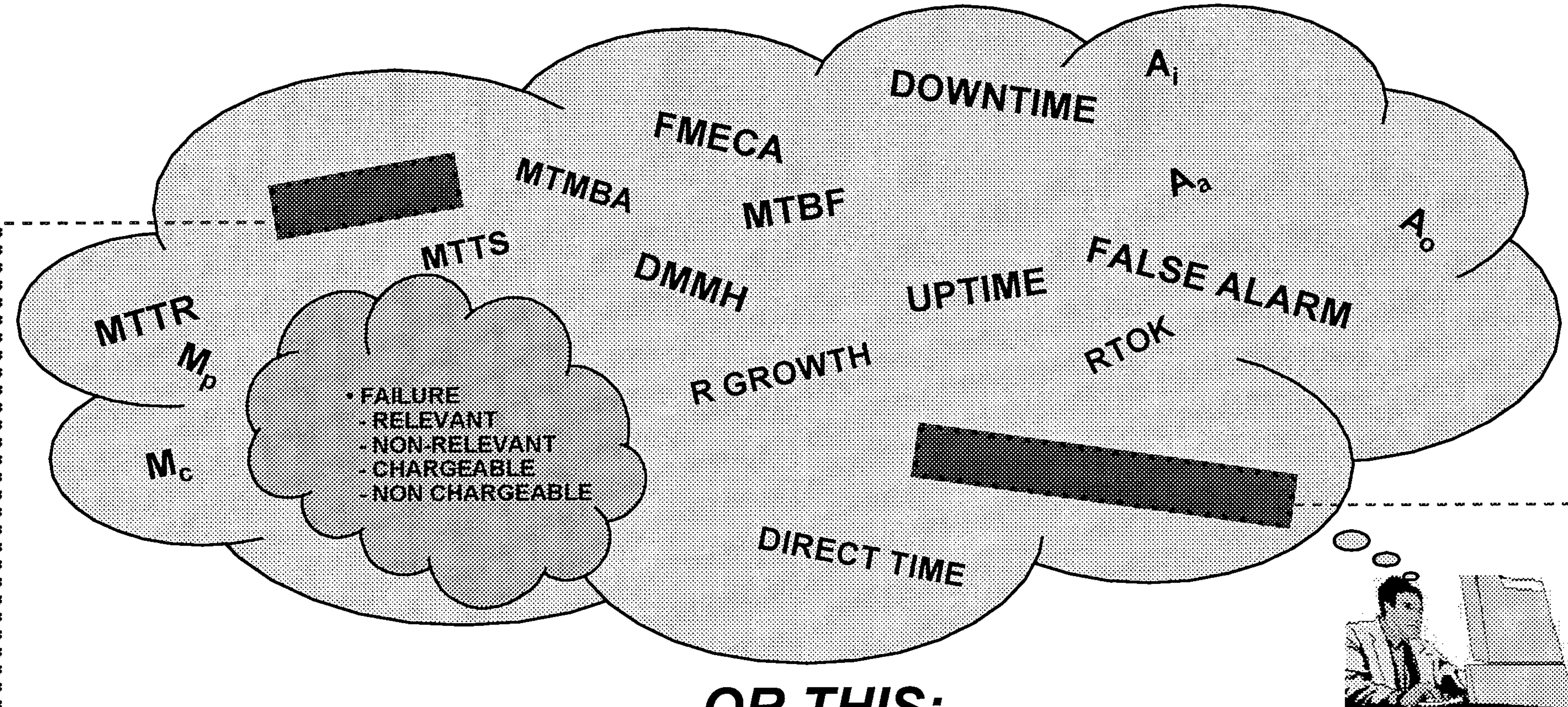


NOTES:
- User learning curve implies initial fielding problems
- PDTRs (producibility design-to requirements)
- SDTRs (supportability design-to requirements)
- MFG/support event
  f = frequency
  d = duration

SUPPORTABILITY ENGINEERING

Does the Design Engineer Really Need All This?

TRW



OR THIS:

▶ System/Subsystem Specification: "The directional control computer shall contain BITE circuitry that tracks within the full range of control surface positions and is impervious to variations in system ground levels (±0.5v DC)." ◀

The Real Issue: Let's make it easy for the designer by making supportability transparent through simple and direct specifications.

TRW's Supportability Approach Emphasizes Support Event Analyses Beyond A_O

TRW

TRADITIONAL APPROACH

OPERATIONAL AVAILABILITY (A_O)
MIL-STD-1388

THE PROBABILITY THAT, WHEN USED UNDER STATED CONDITIONS, A SYSTEM WILL OPERATE SATISFACTORILY AT ANY TIME. A_O CAN BE EXPRESSED BY THE FOLLOWING FORMULA:

- $A_O = \dfrac{OT + ST}{OT + ST + TCM + TPM + A/LDT}$

WHERE:

- OT = TOTAL OPERATING TIME DURING A SPECIFIC INTERVAL
- ST = TOTAL STANDBY DURING A SPECIFIED INTERVAL
- TCM = TOTAL CORRECTIVE MAINTENANCE TIME DURING THE SAME SPECIFIED INTERVAL
- TPM = TOTAL PREVENTIVE MAINTENANCE TIME DURING THE SAME SPECIFIED INTERVAL
- A/LDT = TOTAL ADMINISTRATIVE AND LOGISTICS DOWNTIME DURING THE SPECIFIED INTERVAL

- HENCE A_O ADDRESSES

SUPPORT PL
(PEACETIM

TRW APPROACH

$A_O \overset{?}{=}$ SUPPORTABILITY (S)

- GIVEN: $A_O = \dfrac{OT + ST}{(?) + OT + ST + TCM + TPM \text{ E } A/LDT}$

(?) $\rightarrow$ MISSING SUPPORT EVENTS

- SERVICING
- RECONFIGURING
- GROUND/CARRIER HANDLING
- HOT AND COLD COMBAT TURNS
- SORTIE ACTIVITIES
- MISSION VARIATIONS
- OTHER

THEREFORE, A_O ° S

- BECAUSE: S IS NOT ADDITIVE BUT CONSISTS OF FINITE, SIMULTANEOUS SUPPORT EVENTS

HOWEVER S = F (OPERATIONAL SUITABILITY, READINESS, SUSTAINABILITY, SURVIVABILITY, MOBILITY, LIFE CYCLE COSTS, A_O)

- WHERE: S = F (f, d,c) OF ALL SUPPORT EVENTS

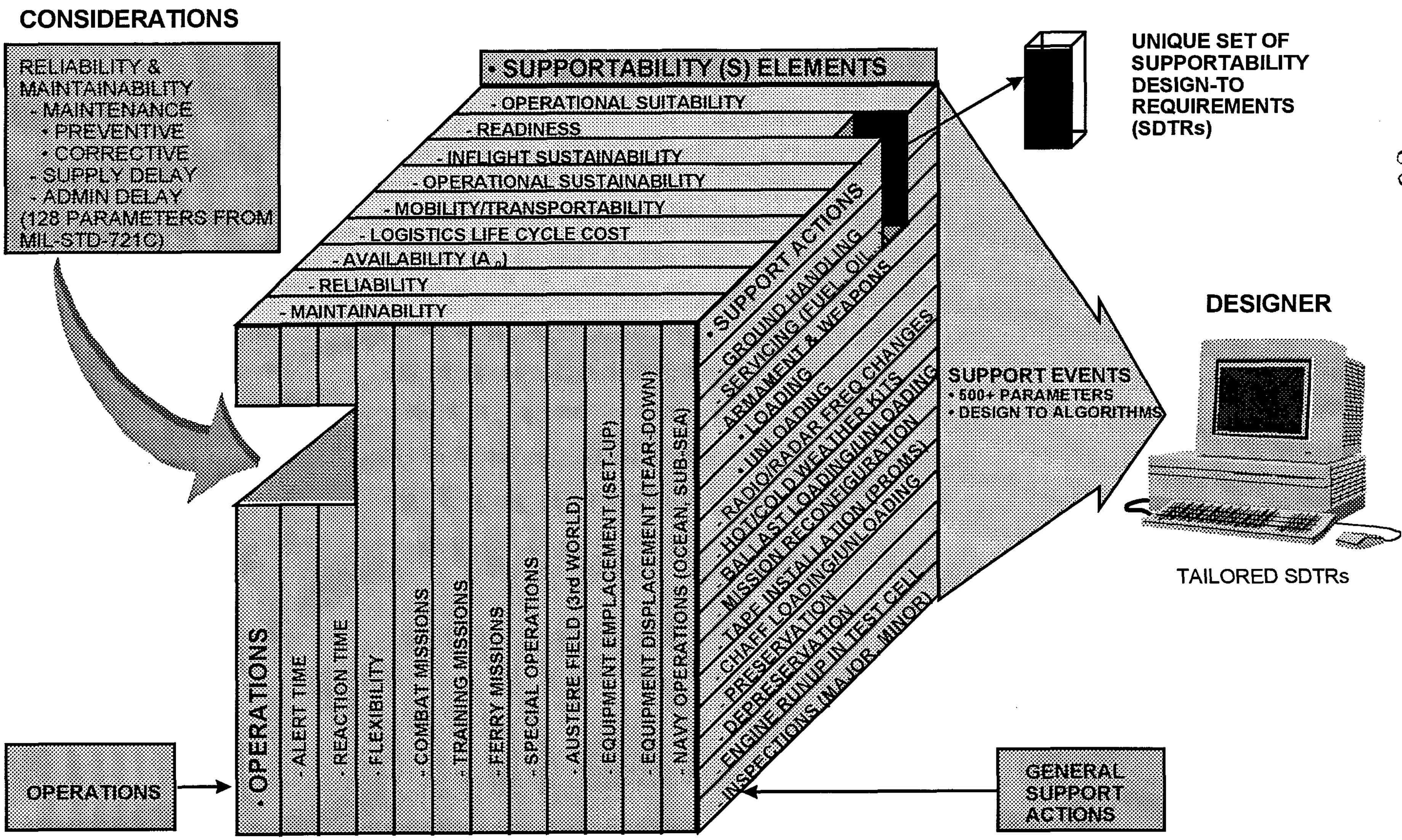
f = SUPPORT EVENT FREQUENCY
d = SUPPORT EVENT DURATION
c = SUPPORT EVENT COST

- HENCE, SUPPORTABILITY ADDRESSES

DESIGN FOR S
(WARTIME OP

Integrated Considerations Result In Tailored Supportability Design-To Requirements

TRW



Supportability Assessment Process of Fielded Systems Results in Affordable Readiness

TRW

Use Knowledge-aided Supportability Analysis Technique (KSAT) to develop Supportability Design-To Requirements (SDTRs)

- SDTRs serve as guidelines for ensuring broad spectrum supportability results (cost, mission, etc..)

Comprehensive Integrated Support Planning (ISP)

- Addresses all impacts on System Life Cycle

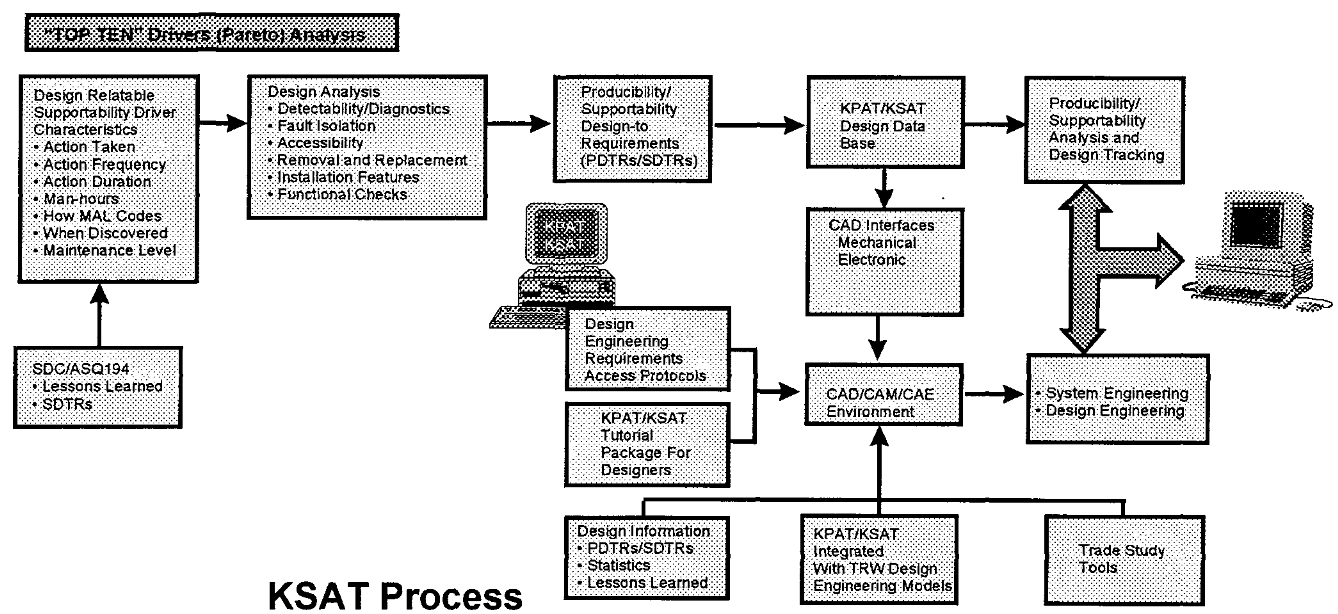
Level Of Repair Analysis (LORA)

- Identifies opportunities for support planning streamlining

Life cycle costing including organic Vs. contractor studies

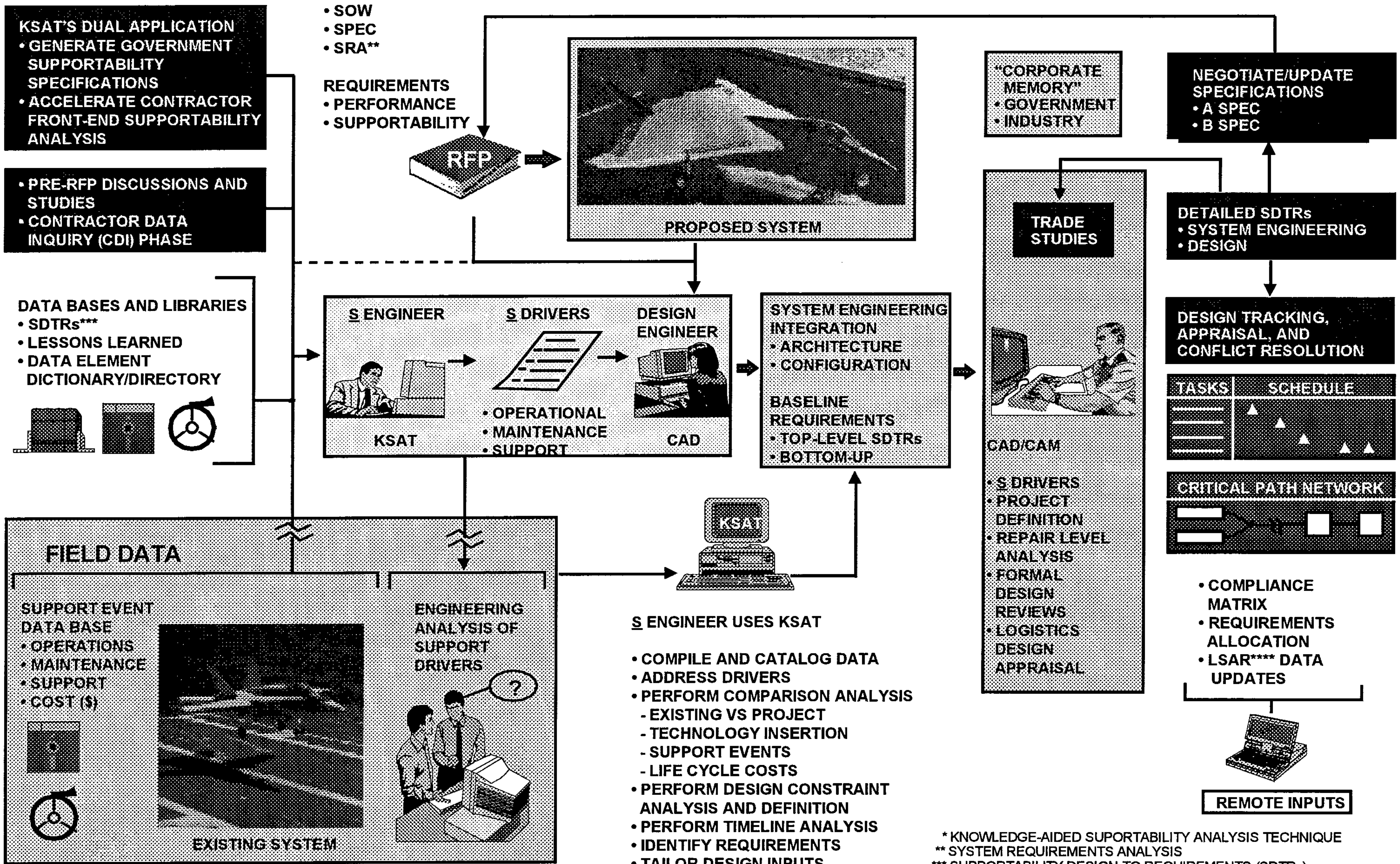
- ROI analyses to support appropriate LECP Processes

- Pinpoints opportunities for technology insertion to improve supportability



KSAT Process

The KSAT* Augments Supportability (S) Design Analysis



* KNOWLEDGE-AIDED SUPORTABILITY ANALYSIS TECHNIQUE
** SYSTEM REQUIREMENTS ANALYSIS
*** SUPPORTABILITY DESIGN-TO REQUIREMENTS (SDTRs)
**** LOGISTICS SUPPORT ANALYSIS REQUIREMENTS

SIGNAL DATA COMPUTER (SDC) SUPPORTABILITY ANALYSIS

Paul Blackwell

Supportability Engineer

North Island Naval Air Station

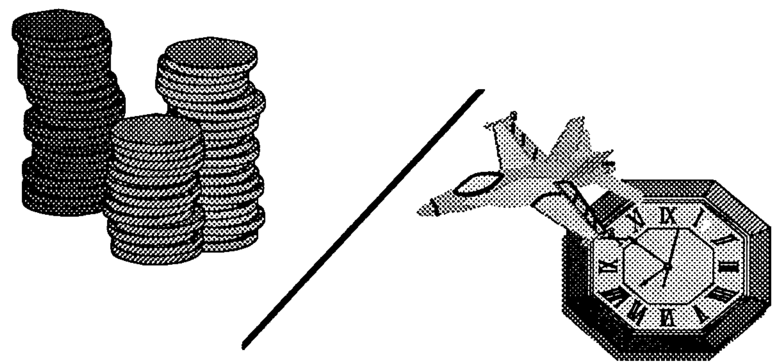
Naval Aviation Depot

SDC Identified As F/A-18 High Cost Per Flight Hour. TRW

Solution: *Modify SDC?*

Process Used: KSAT

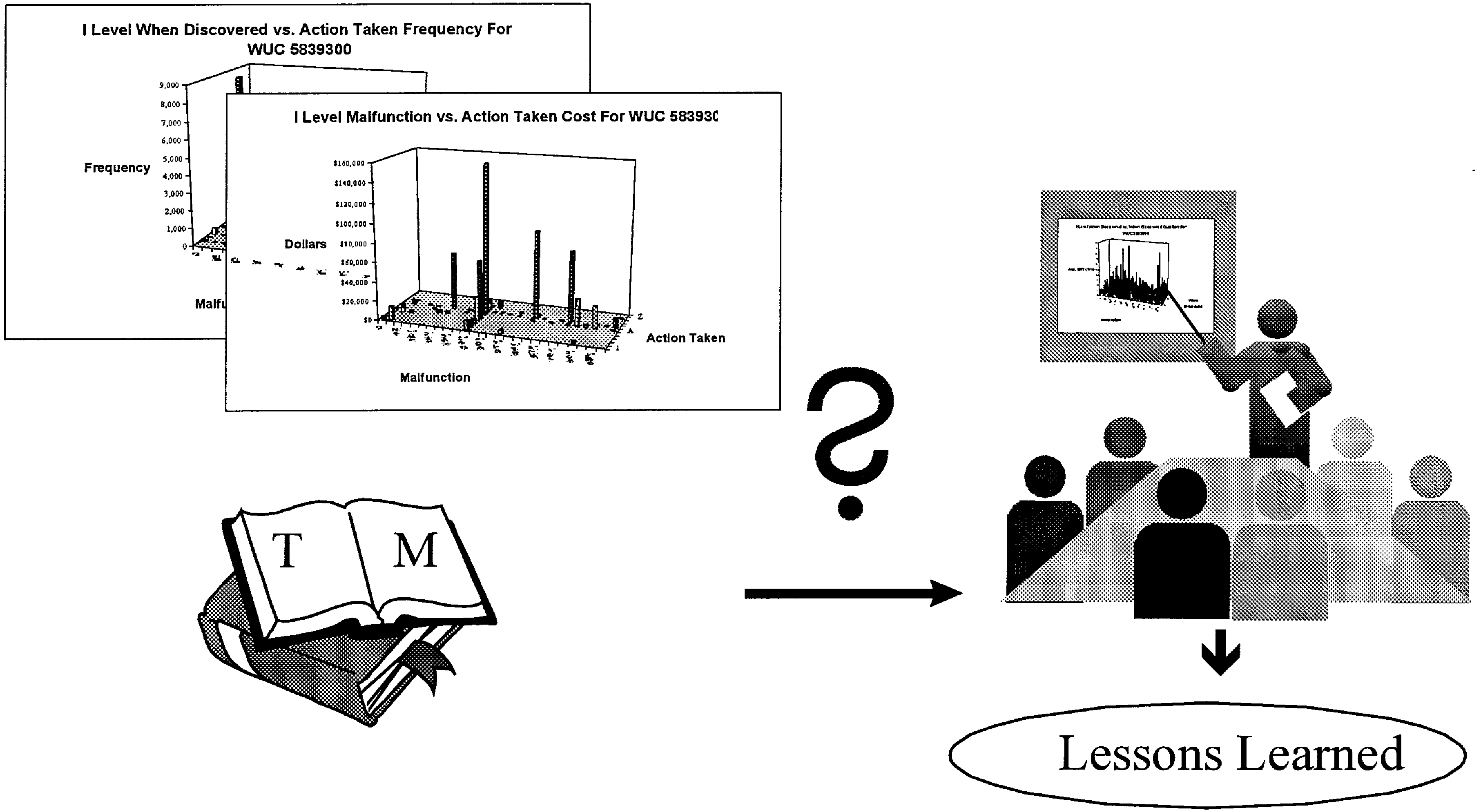
=



SDC Engineering POC:	Garth Michaelis 55093
Supportability POC:	Paul Blackwell 59944

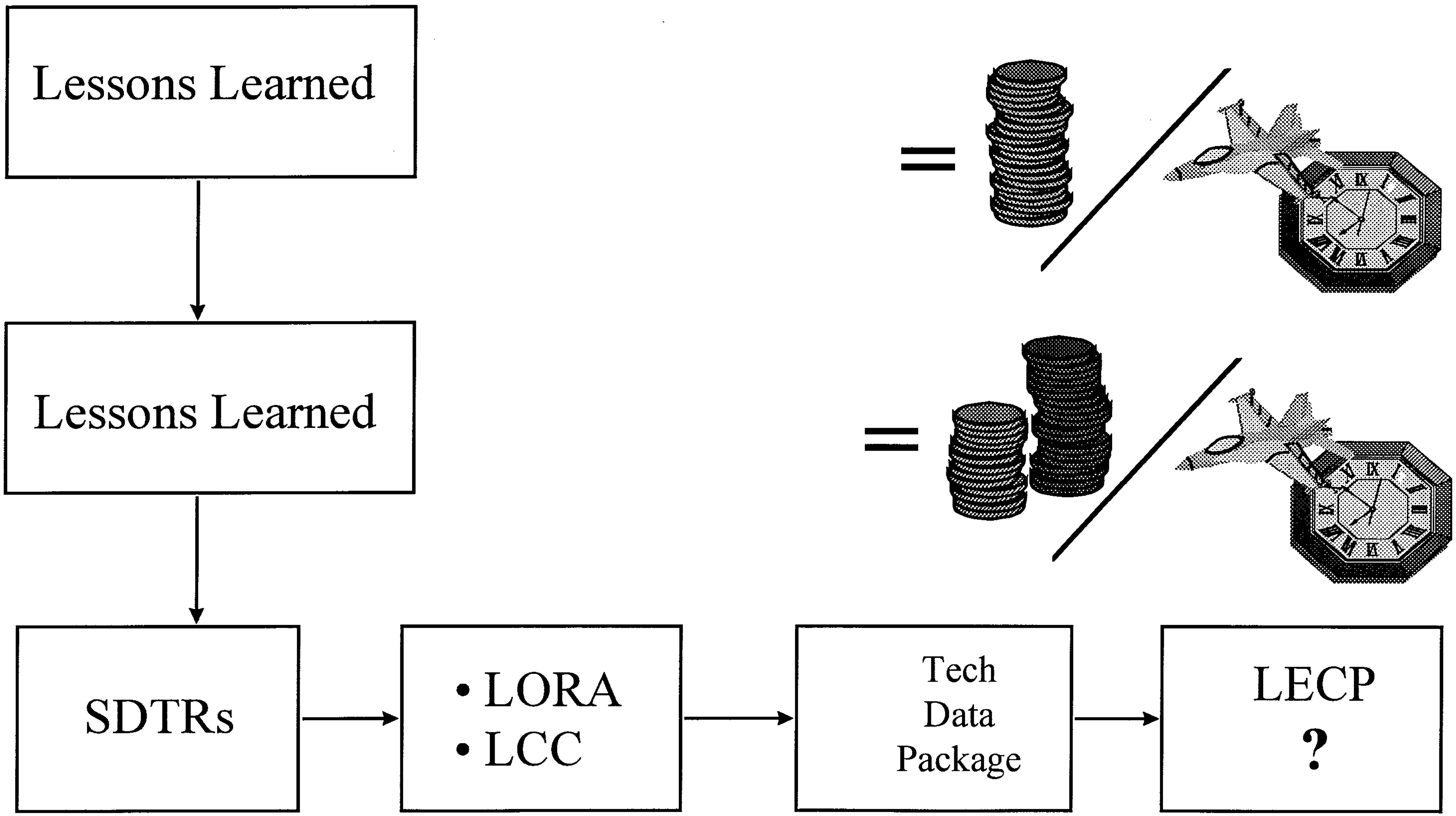
TRW

Bivariate Analyses Of Support Event Degraders And Tech Manual Review Provide Format For Discussion Of Fleet's Technical Challenges



Lessons Learned Generate Supportability Design-To Requirements (SDTR). SDTRs Are Solution Set For Technical Data Package

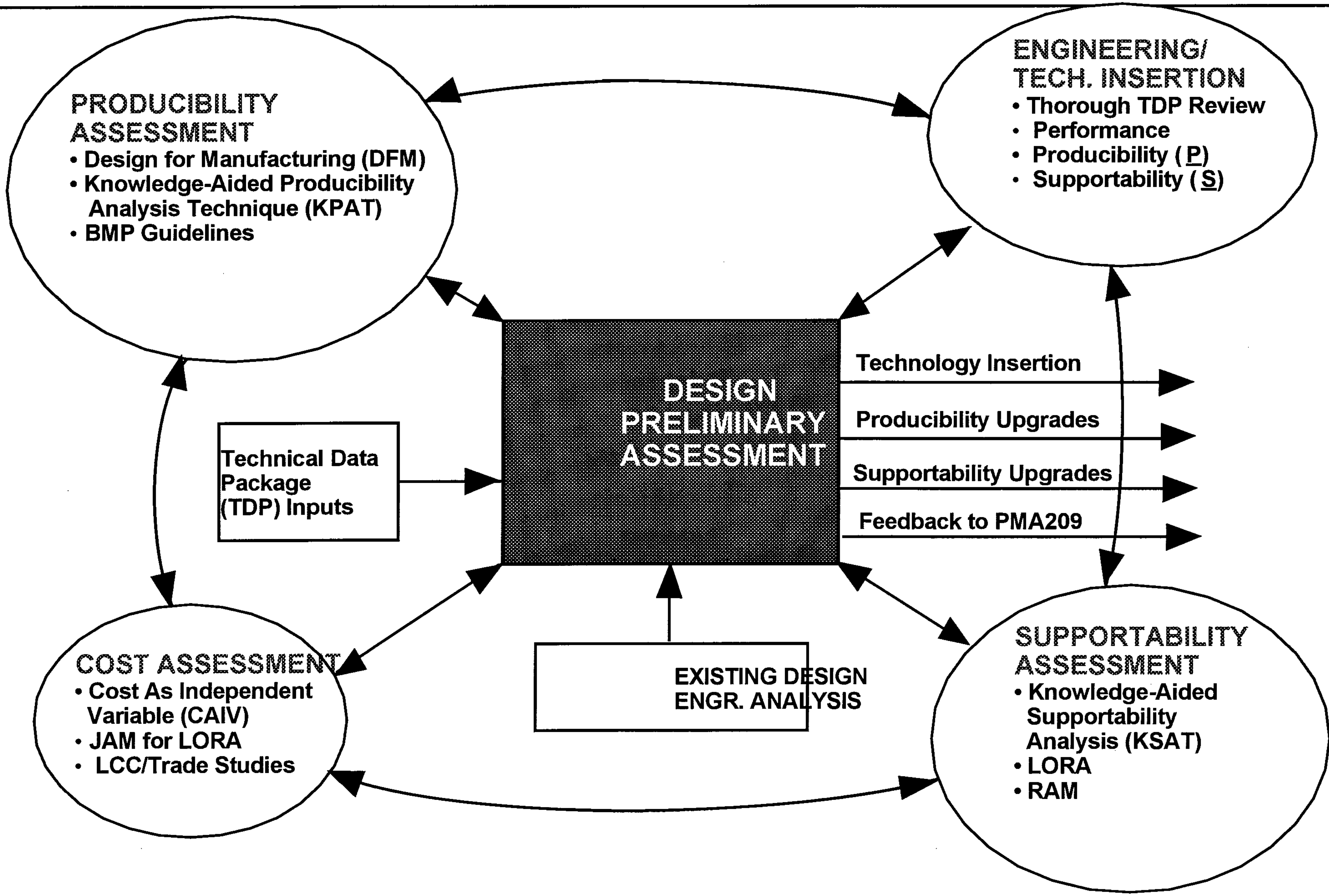
TRW



WRAP-UP

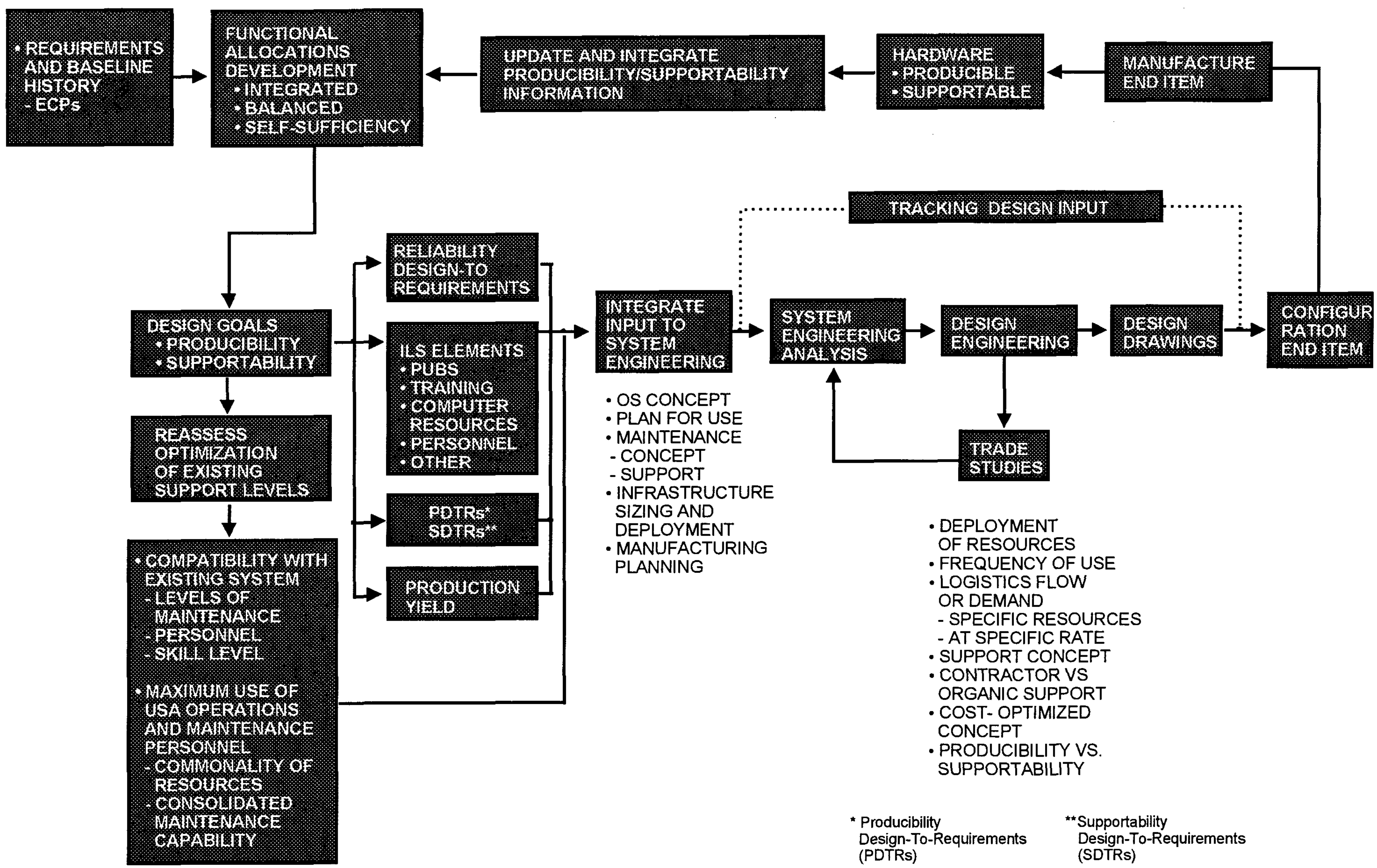
Fielded Systems Benefit from Producibility and Supportability Engineering Improvements

TRW



Integrated Engineering Change Proposals (ECPs) Assure Effective Acquisition of New End Items

TRW



* Producibility Design-To-Requirements (PDTRs)

**Supportability Design-To-Requirements (SDTRs)

CONCLUSIONS

TRW

In today's world of increased pressures in

- declining defense budgets
- rising costs
- fast-paced upgrades to existing systems
- and increased design complexities

The IPT offers a streamlined process for requirements definition,

particularly when augmented by knowledge-aided techniques

The results benefit both customer and industry

National Defense Industrial Association (NDIA) Systems Engineering & Supportability Conference and Workshop

Open Systems Approach - Integrated Diagnostics Demonstration (OSAIDD) Program

Mr. James Bohr
NAWCAD Lakehurst
(732)323-1947
bohrjs@lakehurst.navy.mil

Topics of Discussion

- Background
- Objectives
- Team
- Research Approach
- Findings
- Recommended Approach
- Recommended Actions and Expected Benefits
- Roadmap

Project Background

OSD Integrated Diagnostics Initiatives

- GIMADS and IDSS Programs of the 1980's
- Program Element initiated in FY1990 for integrated diagnostic demonstrations
  - Shipboard Mechanical Diagnostics Demonstration (CBM for HM&E)
  - Missile Integrated Diagnostics Demonstration (IDD) for the Patriot
  - F/A-18 Aviation Maintenance IDD most recently completed project that integrated flight line diagnostic elements
  - Joint Factory-to-Field Integration of Defense Test Systems Project initiated in 1995
  - Trident Missile Launcher Demonstration
  - Diagnostics for Acquisition
- August 1996 Joint Service Integrated Diagnostic Workshop

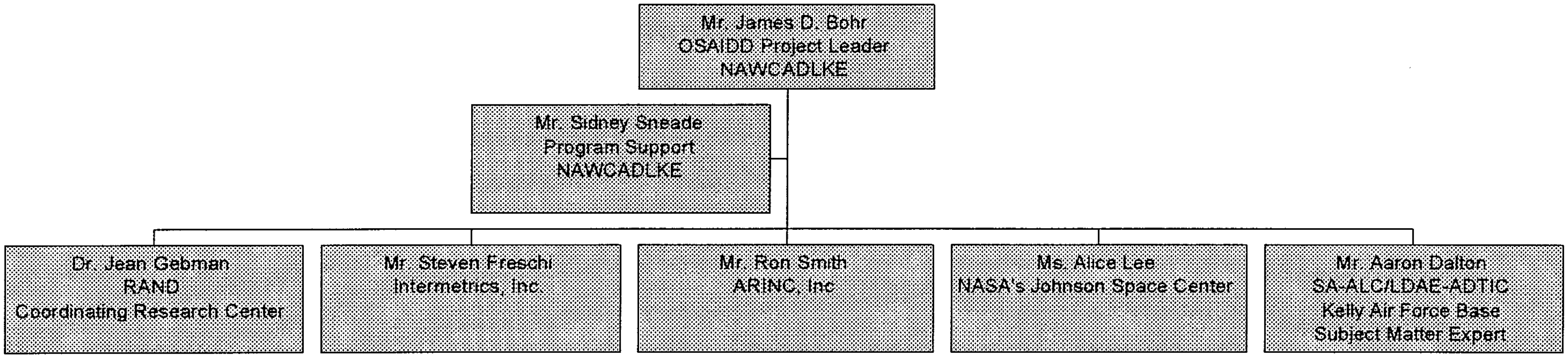
Related Initiatives

- Automatic Test System (ATS) Policy in 1992 established DoD ATS families and use of "critical interfaces and elements" to migrate towards a common solution
- F-16 Integrated Maintenance Information System
- Helicopter Health Use Monitoring Initiatives (RITA, H-53 IMD and JAHUMS)
- The Army's Diagnostic Improvement Program (ADIP) initiated in 1997

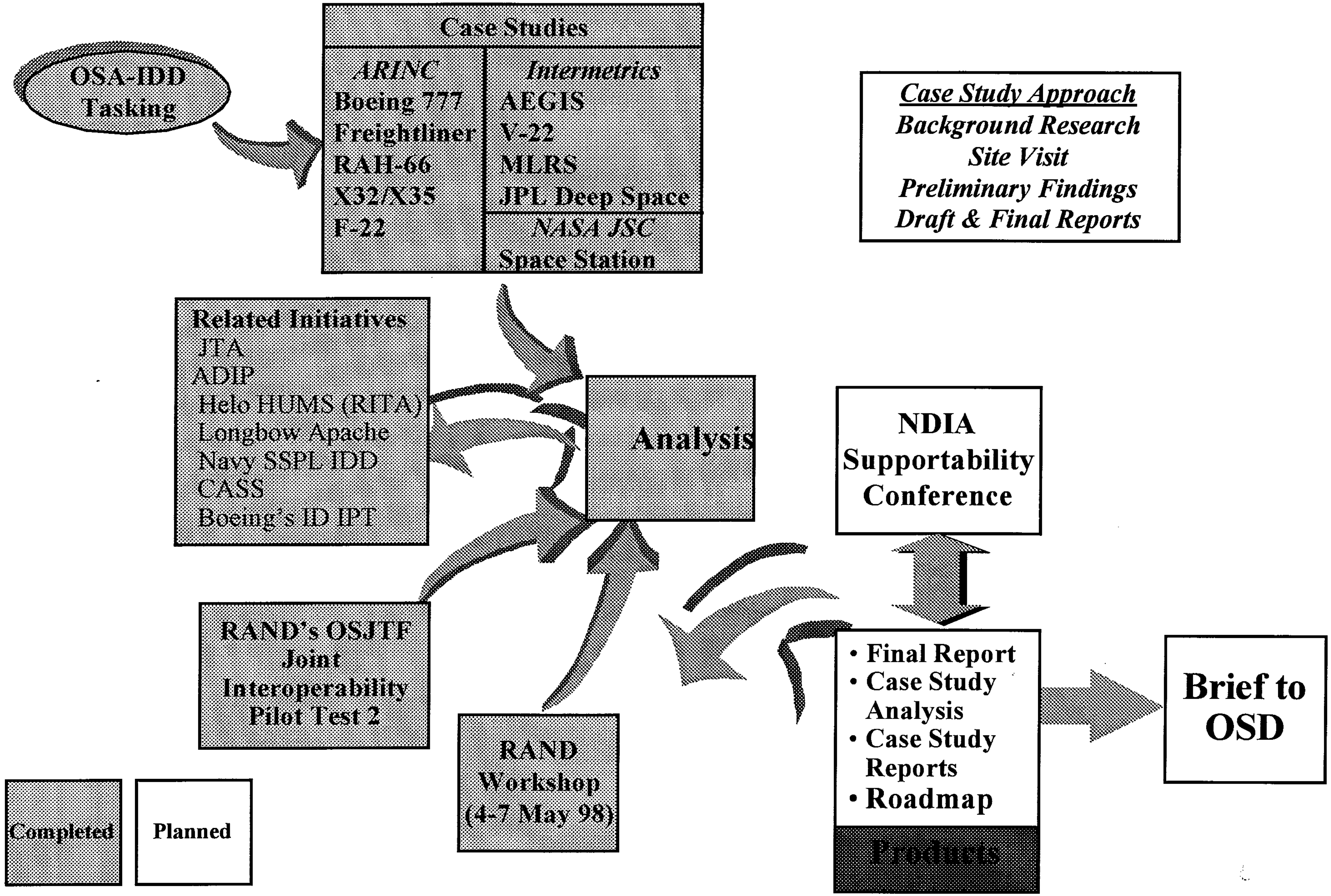
External Factors and Policy

- Fiscal Constraints and Infrastructure Reductions
- Acquisition Reform and the Elimination of Military Specifications and Standards
- Increasing Use of Commercial Items
- Open Systems Joint Task Force (OSJTF) and Joint Technical Architecture (JTA)

OSA-IDD Program Team



OSA-IDD Program Approach



Open System Goals and Objectives for Integrated Diagnostics

Strategic Goals

- *Reduced Cost*
- *Increased Interoperability*
- *Faster Technology Insertion*

Diagnostic-Related Tactics

- *Insight to Operation & Support Costs*
- *Rapid Product Maturation*
- *Higher Confidence in Fault Isolation*
- *Leverage Information from CAD/CAM for diagnostics*
- *Commercial Products & Processes*
- *Favorable System Architectures*
- *Flexible Diagnostic Architectures*

Specific Objectives

- *Identify Critical Interfaces and Elements*
- *Consistent Model of Diagnostic-related Information*
- *Interchangeable Sensors & Instruments (hardware)*
- *Interchangeable Diagnostic Algorithms (software)*
- *Consistent, Measurable Diagnostics Process & Metrics*
- *Integration of Diagnostics with Design & Engineering*
- *Advanced Communication Technology*

Findings

Diagnostic Trends

- Increasing system complexity and integration
- Models as basis of diagnostic design and functionality (model-based diagnostics)
- Increasing system autonomy (machine learning)
- Dedicated diagnostic subsystems (area managers)
- Communication of component-level behavior for self-reporting.
- Standard communicating methods for diagnostic data
- Obsolescence as design consideration, source of hardware changes and opportunity to affect diagnostics
- Information systems as means for affecting legacy systems

Findings

Keys to Success

- Reducing diagnostic ambiguities and inaccuracies
- Effective use of information
- Correlation of diagnostics with operational performance
- Business dynamic with incentives to improve performance and reduce cost
- Complementary infrastructure systems (MIS/DSS)
- Measurable and relevant metrics
- Empowered advocacy within purchasing/acquisition
- Industry standards facilitated by a domain specific organization

Findings

Diagnostic Challenges

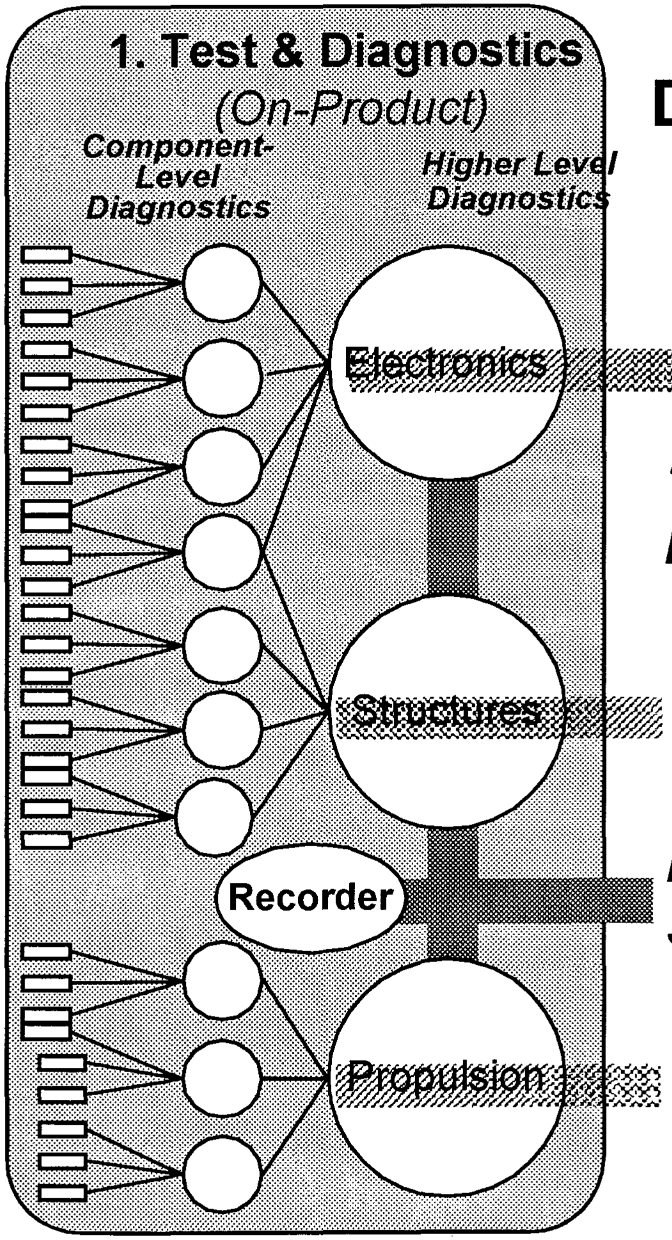
- Improving the use of information
- Effective human-machine interface (HMI)
- Isolating and affecting sources of diagnostic ambiguities & inaccuracies
- Improving legacy systems
- Improving the on-off product interface
- Standard BIT/diagnostic data encapsulation
- Validation and verification of diagnostic performance
- Systems engineering methods/tools to support diagnostics
- Prognostics (electrical)
- Effective implementation of artificial intelligence
- A consistent architecture for integrating diagnostic elements

Findings: *Diagnostic Functions and the On-Product Test and Diagnostics Component*

Sensor Characteristics

Measurements:
- **acceleration**
- **pressure**
- **force,**
- **etc.**

Signals Generated:
- ***Frequency***
- ***Velocity***
- ***Inductance***
- ***Resistance***
- ***etc.***



Diagnostic Functions

Core Diagnostic Functions

Fault Detection
Fault Recovery
Fault Isolation
Corrective Action

Test Sub-Class of Functions

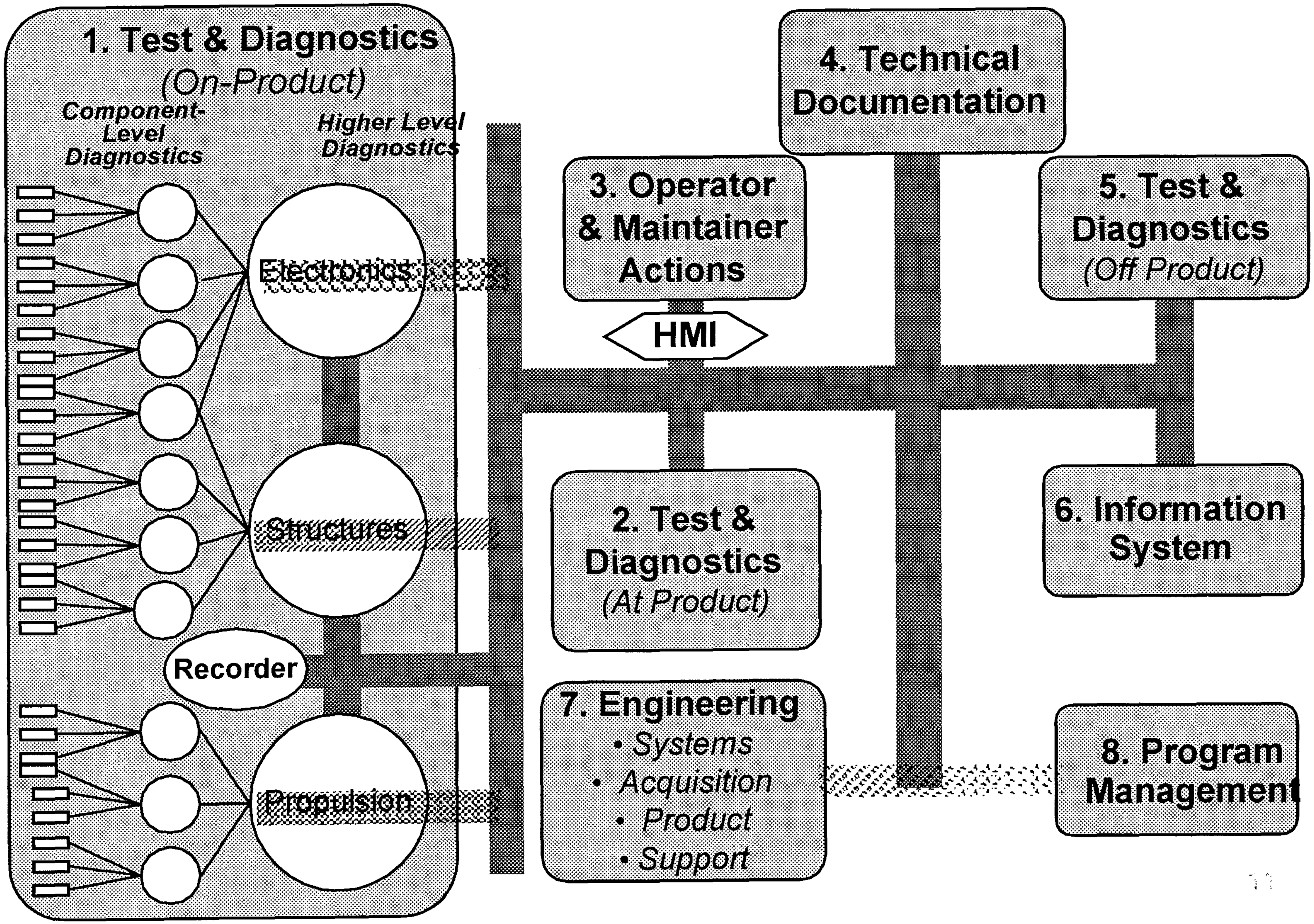
Stimulus
Measure
Compare
etc.

Information Fusion Sub-Class of Functions

Trend Analysis
Machine Learning
Data Mining
etc.

Findings

Diagnostic-related Components, Interfaces and Partitions



Recommended Approach
An Expanded Definition of Integrated Diagnostics

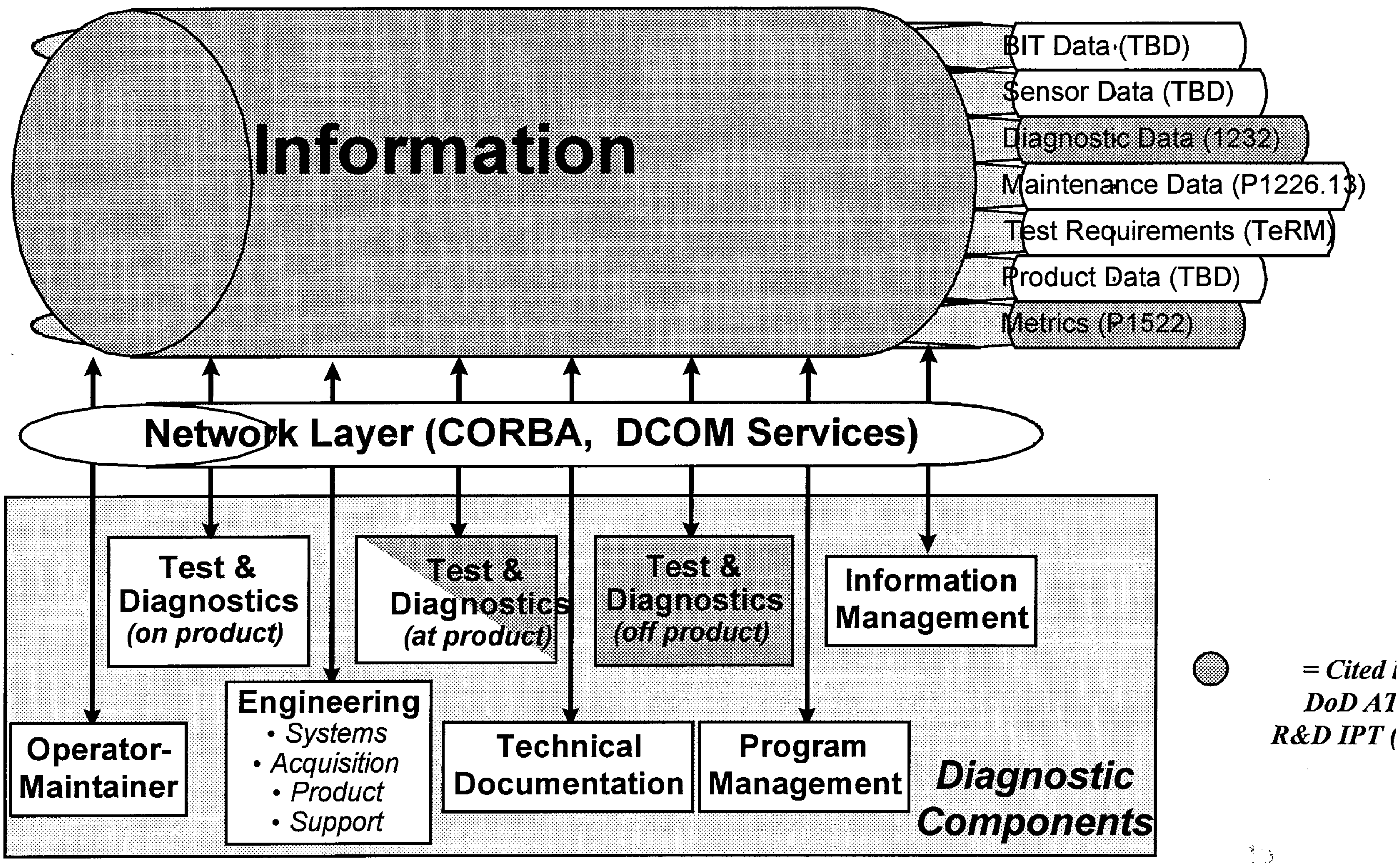
"...a structured process which maximizes the effectiveness of diagnostics by integrating the individual diagnostic elements of testability, automatic testing, manual testing, training, maintenance aiding, and technical information." Keiner, 1990

"...represents a systems approach where integrating diagnostic elements creates a total diagnostic capability that outperforms individual support and maintenance tools operating alone." Brown, 1996

"...is part of the systems engineering (or reengineering) process in which diagnostic functions are partitioned to components, both on and off the product, to optimize economic and functional performance throughout a products life cycle. Optimal performance is achieved by ensuring effective communication of information relevant to the test and diagnostic process occurs between diagnostic functions and components and across each life cycle phase." OSAIDD Study, 1998

Recommended Approach

An Information-Based Integrated Diagnostic Architecture



Recommended Actions and Expected Benefits

Architecture

Formally Define and Model Information in the Diagnostics Process	• Effective capture and use of diagnostic <u>information</u> • Consistent diagnostic metrics • Faster diagnostic maturation • Consistent basis for evaluating a product's integrated diagnostic capability • Reduced diagnostics development time and cost
Demonstrate and Implement a "Plug-and-Play" Diagnostic Sensor Architecture (hardware)	• Faster, Less Costly Technology Insertion • Obsolescence Management • Continuous diagnostic performance improvement • Reduced sustainment cost and manpower
Demonstrate and Implement a "Plug-and-Play" Diagnostic Algorithms Architecture (software)	• Increase use of COTS • Increase competitive base among suppliers • Reduce sustainment cost and manpower • Improved prognostics and condition-based maintenance
Demonstrate and Implement a Consistent Approach to Component-Level Built-in-Test (BIT) Data	• Increased maintenance efficiency & accuracy • Reduced manpower • Reduced ambiguity (i.e., could-not-duplicates, no-faults-found, etc.)

Recommended Actions and Expected Benefits

	Recommended Action	Expected Benefits
Technology	**Demonstrate and Implement Advanced Communication Technologies for Off-Product Diagnostic Data Transmission**	• Enable effective communication • Reduced cost and maintenance time • Increase Maintenance efficiency
	Demonstrate Benefits of Applying Functional Description Languages to Diagnostics	• Increase diagnostic confidence • Reduced development cost for diagnostics • Simulateable functional models for hardware and software
Engineering Tools	**Demonstrate and Implement a Consistent Approach to Sharing Information between the Design, Test and Diagnostic Processes**	• Better diagnostics sooner • Modeling and simulation tools to increase confidence of designs • Validation and verification of diagnostics

5

Recommended Actions and Expected Benefits

Policy

Establish OSD-level Advocacy and Leadership

- Enable life cycle cost reduction and diagnostic maturation
- An OSD-Level Agent to broker enabling guidance/policy
- A DoD Center of Excellence to target research & development
- Collaborations with industry consortia

Acquisition Guidance and Education Initiatives

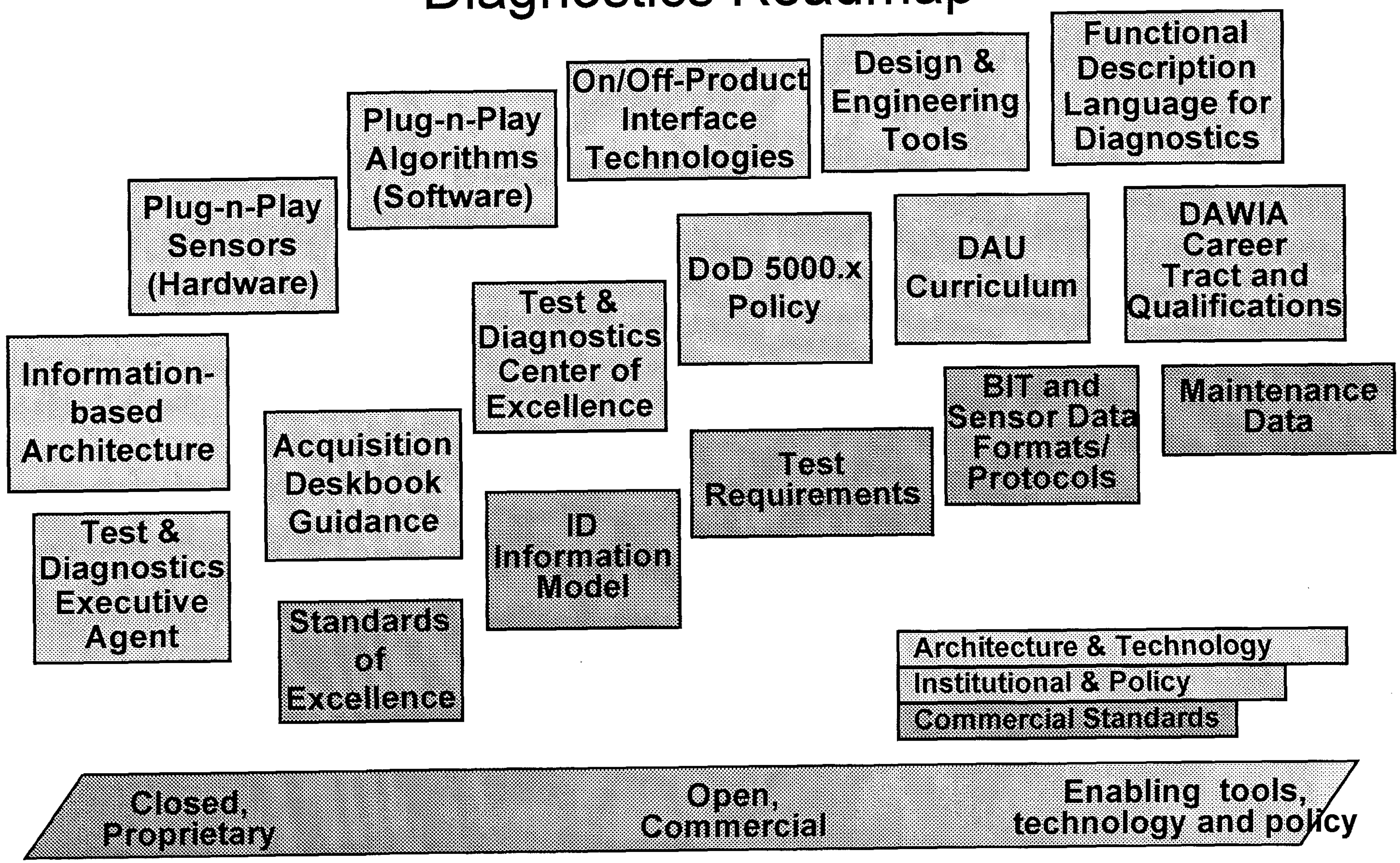
- Project Manager guidance in Acquisition Deskbook
- Curriculum at Defense Acquisition University
- Enable open systems approaches
- Favorable contract structures

Standards

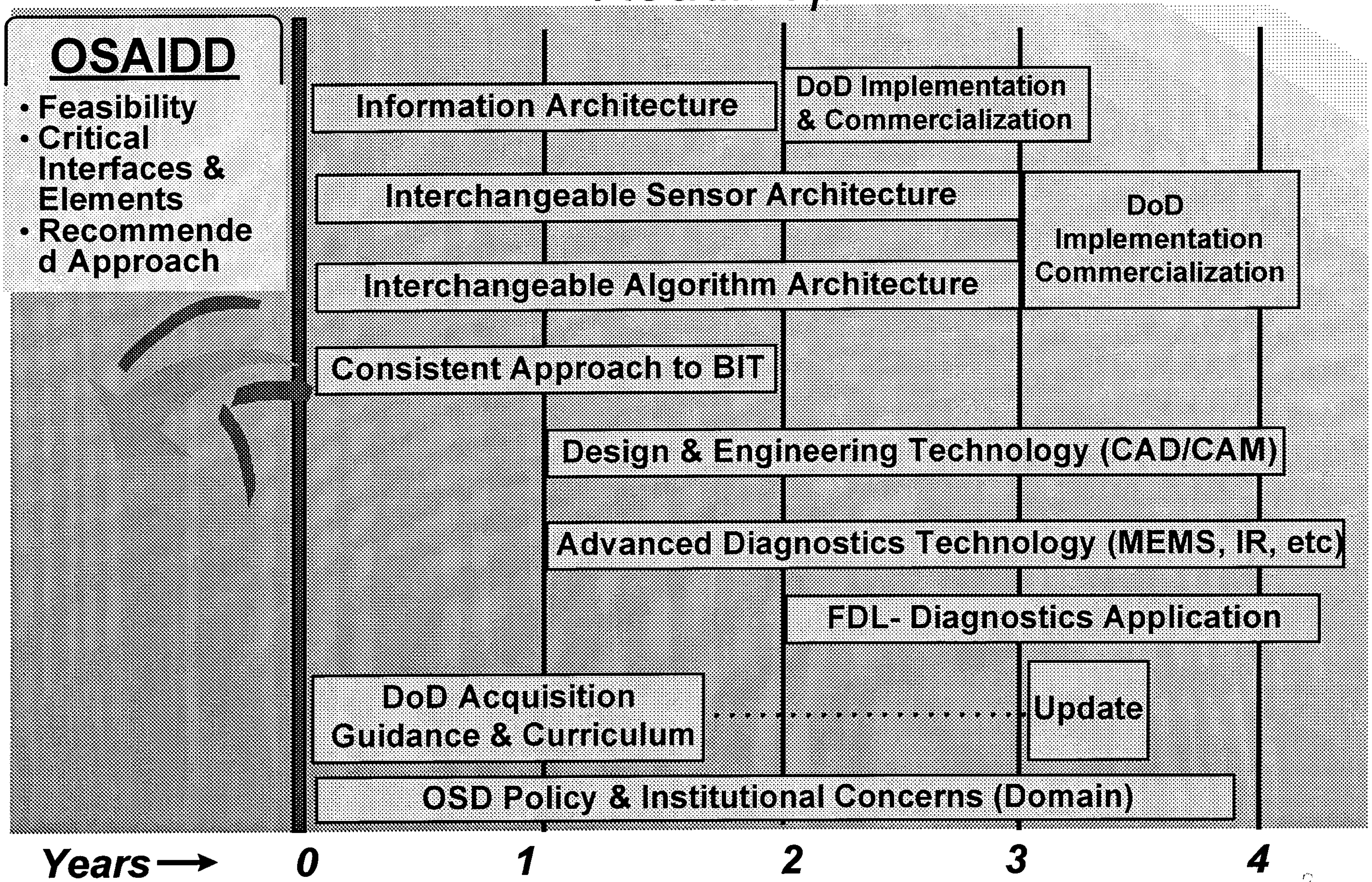
Participate in Commercial Standards Development efforts and Industry Consortia

- Standards of excellence for diagnostics
- Transfer demonstrated technology and processes to commercial supplier base
- Affect supplier base from focused customer perspective
- Reduce cost of technology insertion

Open Systems Approach for Integrated Diagnostics Roadmap



An Integrated Diagnostics Architecture
Roadmap



Summary

- A consistent approach **is** possible for integrating diagnostic capability yielding implementations that:
  - reduce cost
  - increase interoperability
  - enable faster technology insertion
  - leverage investments across legacy and developmental systems
- OSA-IDD Program has provided:
  - A consistent approach to implementing integrated diagnostic functions
  - Important elements & interfaces of a consistent architecture
  - Roadmap for architecture maturation and implementation
- Targeting Industry Consortia for broad, cross-domain acceptance and participation

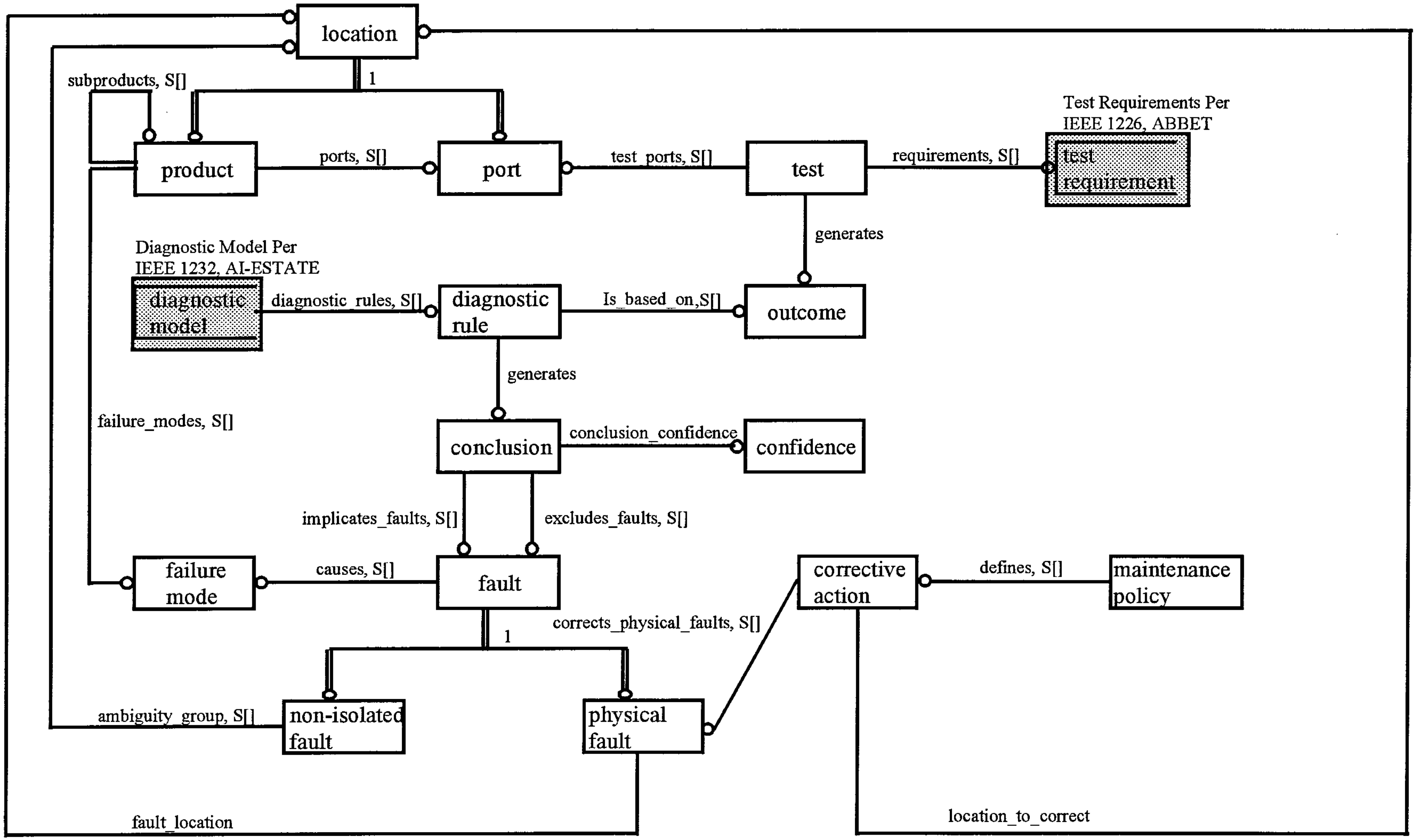
Back-up Slides

Case Study Selection Rationale

— Medium level of NAWC interest = High level of NAWC interest * Lead for point of contact		JSF	777	CASS	IFTE	AEGIS	V-22	MLRS	COMANCHE	COM SAT	LB APACHE	CATAPULT	COM SHIP	Frt LINER	F-22
Goals	**Tactics**														
1. Reduce costs through common use 2. Reduce costs with better diagnostics 3. Improve availability	**Integrated electronics architecture**	$\underline{X}$	$\underline{X}$						$\underline{X}$					$\underline{X}$	$\underline{X}$
	Fault isolation system	$\underline{X}$	$\underline{\underline{X}}$	$\underline{\underline{X}}$	X	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{\underline{X}}$	$\underline{X}$	X	X	X	$\underline{\underline{X}}$	$\underline{\underline{X}}$
	Commercial alternatives	$\underline{X}$	X $\underline{X}$	$\underline{X}$	X	$\underline{X}$	$\underline{X}$		$\underline{X}$	X $\underline{X}$			X X	X $\underline{X}$	$\underline{X}$
	Facilitated domains		$\underline{X}$												
Research Priorities (1: Highest 6: Lowest)	RAND	5*	1*	1		2	4	3*	3*	6				2*	4*
	ARINC	$\underline{5}$	$\underline{\underline{1}}$						$\underline{3}$	$\underline{6}$				$\underline{\underline{2}}$	$\underline{4}$
	Intermetrics			$\underline{\underline{1}}$		$\underline{\underline{2}}$	$\underline{4}$	$\underline{3}$							
	NAWC	5	1	1*		2*	4*	3	3	6				2	4

An Integrated Diagnostics Architecture

An Information Model View



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Wide Area Integration: Innovation for the Virginia Class Submarine

Thomas P. Conrad
conradtp@csd.npt.nuwc.navy.mil

NDIA Systems Engineering
& Supportability Conference
September 1998

Virginia (SSN 774) C3I System

(Pictorial of Attack Center)

Non-Propulsion Electronics System Challenges

Objectives

- Affordability
- Meet Ship Schedule
- Meet Performance Requirements
- Mission Flexibility

Trade-off Studies (1988-present)

Acquisition Reform Initiative

System Engineering

Key Technical Approach

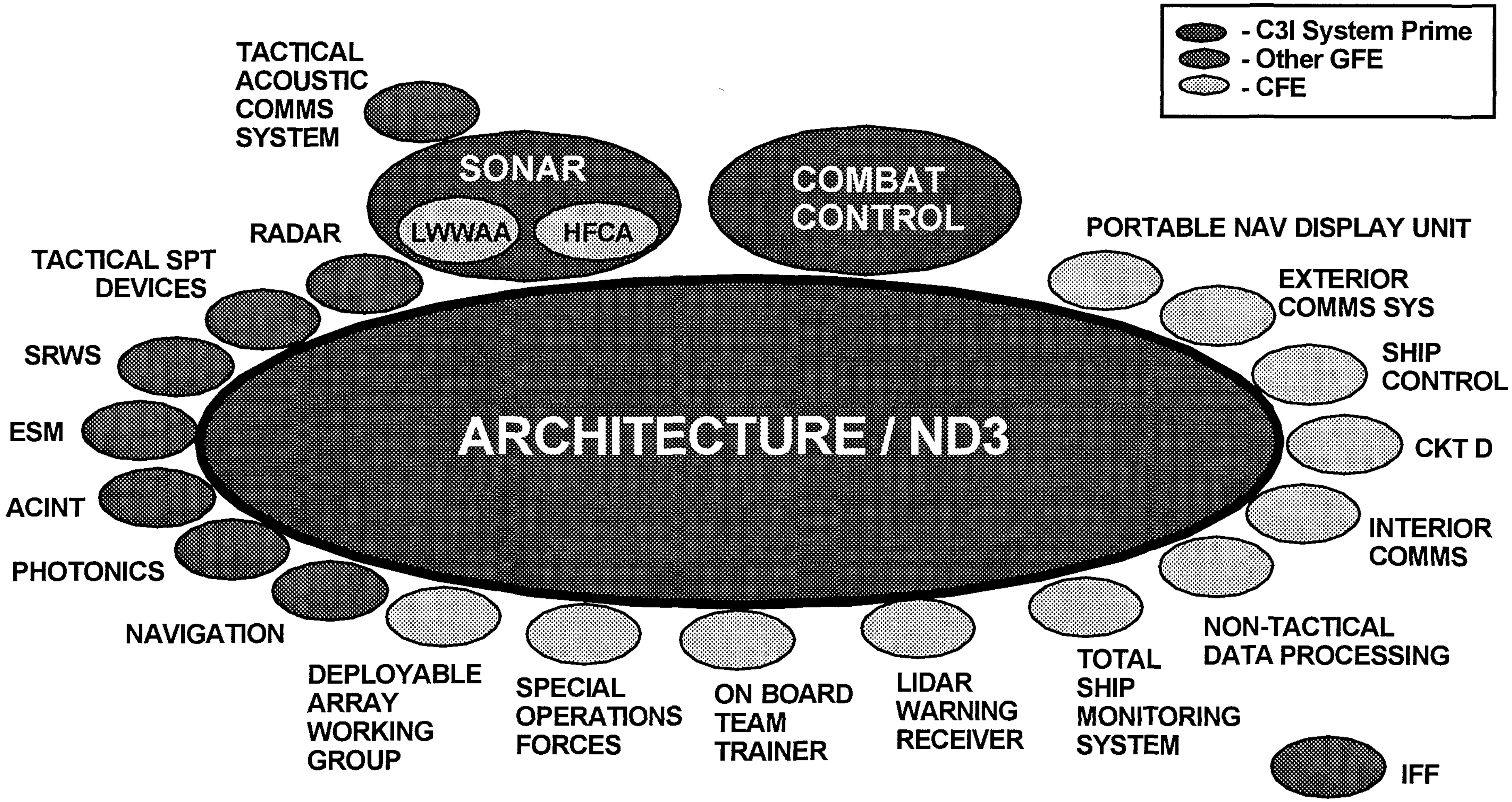
- Commercial-Off-The-Shelf Products
- Open Systems Architecture
- Non-Development Items
- Software Reuse
- Concurrent Engineering
- Modular Integrated Deck Structure/Structurally Integrated Enclosure
- Early Industry Involvement
- Early Customer (Fleet) Involvement

Context of the NPES Acquisition

- A System of Systems
- Federated Computing Resources
- Integrated Information Architecture
- Open System Architecture
- Based on COTS Technologies
- Multiple Parallel Acquisitions of Subsystems
- Early End-User Involvement

[redacted]

Non-Propulsion Electronics System:
- A System of Systems -



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Innovative Integration Approaches

Platform Level Approaches

- Command and Control Systems Module
- Structurally Integrated Enclosure
- CCSM Off-Hull Assembly and Test Site (COATS)

Architecture Oriented Approaches

- Formal Architecture Definition Process
- Risk Reduction Process
- Architecture Topology Definition

Software/System Approaches

- Software-Based Interface Technology
- Data-Oriented Versus Point-To-Point Interfaces
- Wide Area Integration

The Problem of Integration

- NPES is a Large, Complex, Software-Intensive, Real-Time, Mission-Critical, Man-Machine System.
- Affordability Considerations Preclude Establishment of a Traditional Land-Based Integration Test Site.
- Scope of the System and the Acquisition Approach Mandate Multiple, Spatially Distributed Development Sites.
- There is Substantial Risk in Deferring Integration Test Until the System is Assembled Dockside.

New Approach

- Take Advantage of Emerging Network-Centric Development Technology.
- Take Advantage of the System's Client-Server Architecture and Data-Oriented Interfaces.
- Plan for Incremental Integration - Integrate Early and Often.

Define and Implement a Wide Area Integration Capability

Wide Area Integration Facility (WAIF) Definition

The WAIF is the set of hardware and software that serves as the fabric which connects NPES Subsystems to form a virtual development and test facility . This facility will have the capability of emulating the COATS system configuration for test and evaluation purposes.

NPES: Non-Propulsion Electronics System
COATS: CCSM Off-Hull Assembly and Test Site

WAIF Implementation

(WAIF Diagram of Interconnections)

Benefits of WAIF

- The Investment in the WAIF As an Early Integration Mechanism Will Provide an Estimated Return On Investment of ~ 3.7 When Compared to the Projected Cost Growth to the Program (Absent the WAIF) to Fix Problems Associated With Integration of NPES.
- The Use of WAIF and COATS Will Significantly Reduce the Risk of Failing to Achieve Successful Integration on Schedule. Without WAIF, the NPES Ability to Complete a Successful Integration at COATS (Within Cost and Schedule) Is Considered a High Risk.

WAIF Utility (Pre-COATS)

- Facilitate Early Subsystem Interface Development and Test, Both Formal and Informal
- Serve As Pre-COATS Facility for Development and Test of System Management Functions
- Facilitate Pre-Configuration of Subsystems Prior to Delivery at COATS
  - Network Configuration Could Consume 1 Month Out of 9 Months of Costly COATS Test Time
- Support Subsystem Internal Development Testing
  - Architecture Subsystem Test Procedure Development and Internal Test Conduct
  - Sonar to CC Testing Through September 98
- Dry Run COATS Test Procedures

WAIF Utility (COATS)

- Remote Troubleshooting
- Software Updates Provided from Developer's Site
- Support FFR Activities
- Support Secure VTC Linking COATS to Developer's Sites
- Potential Link to Tactical Ship Control System at COATS

New Challenges for Software Integration

- It Is a Difficult Task to Integrate a Large Complex Real-Time Software System Even When the System Is Built to a Detailed Requirements Specification With Full Design Disclosure.
- Consider the Increase in Difficulty When the System Is Assembled From Reused Components, Many of Which Were Built to Serve Broader Marketplace Needs and for Which No Design Disclosure at All Is Available.

Innovative Platform-Level Approaches

- **Command and Control Systems Module (CCSM)**
  - Shock Isolated Deck Structure
  - Modular Construction
  - CCSM Off-Hull Assembly and Test Site (COATS)
- **Structurally Integrated Enclosure (SIE)**
  - Standard Rack
  - Hotel Functions (e.g. water, power, grounding)
  - Maximizes Useable Volume
- **Fiber Optic Cable System (FOCS)**
  - Standardized Cable Plant
  - All Fiber Cabling for NPES
  - Reconfigurable for Future Needs

NPES Architectural Integration

- Architecture Definition Process
  - Maximum Industry Involvement in the Design of the C3I System Architecture
    - » Three Industry Architects Hired (BBN, TRW, AT&T)
    - » Architecture Recommendations Generated
- Risk Reduction Process
  - Architecture Working Group
  - Open Systems Critical Item Tests
- Architecture Topology Defined

Integration Approaches

- **Software-Based Interface Technology**
  - Common Object Request Broker Architecture (CORBA)
  - Object-Based Software Interfaces
  - Software "bus"
  - Location, Language, Implementation, Processor Independence
- **Interfaces Are Data-Oriented Versus Point-to-Point**
  - Data Groups
  - Integrated Product Teams
  - Common Interfaces: 16 Group Interfaces Derive 96 Point-to-Point Interfaces
- **Wide Area Integration**
  - Integrate Early and Often - Risk Mitigator
  - Wide Area Integration Facility (WAIF)
  - Leverages Facilities at all Development Sites
  - Extends Development Facilities into COATS

IMPROVED STANDARDS

FOR

PERFORMANCE BASED SUPPORTABILITY

Presented by

Charles O. Coogan, C.P.L.

ALE Acquisition Logistics Engineering

6797 N. High Street, Worthington, OH 43085

(614) 436-1609 - FAX (614) 436-1295 - staff@ale.com - http:\\www.ale.com

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PRESENTATION OVERVIEW

- History of Supportability Standards
- Performance Based Supportability
- Supportability Standard Development
  - Objective
  - Approach
  - Implementation

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HISTORY OF SUPPORTABILITY STANDARDS

- MIL-STD-472 - Maintainability Analysis
- DARCOM PAM 750-16 - DARCOM Guide to Logistics Support Analysis
- MIL-STD-1388-1, MIL-STD-1388-1A LSA
- The Perry Initiative 29 JUN 94
- SOLE Supportability Re-Engineering Committee
- Early Commercial Supportability Standard Efforts

We've come a long way, but there is a long way to go

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PERFORMANCE
BASED
SUPPORTABILITY
A Systems
Approach to
Availability
ALE

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PERFORMANCE BASED SUPPORTABILITY OBJECTIVE

Change the mind set from:

- Large volumes of analysis and data
- Supportability as a separate discipline
- Supportability being "equal" with performance
- Supportability being good if you can afford it

To:

- Supportability as a performance measure
- Supportability allocation as a systems engineering responsibility
- Design for supportability as a design responsibility
- Support system design is a logistics engineering responsibility
- Operating support systems as a product support function

All Done as an Integrated Product Team

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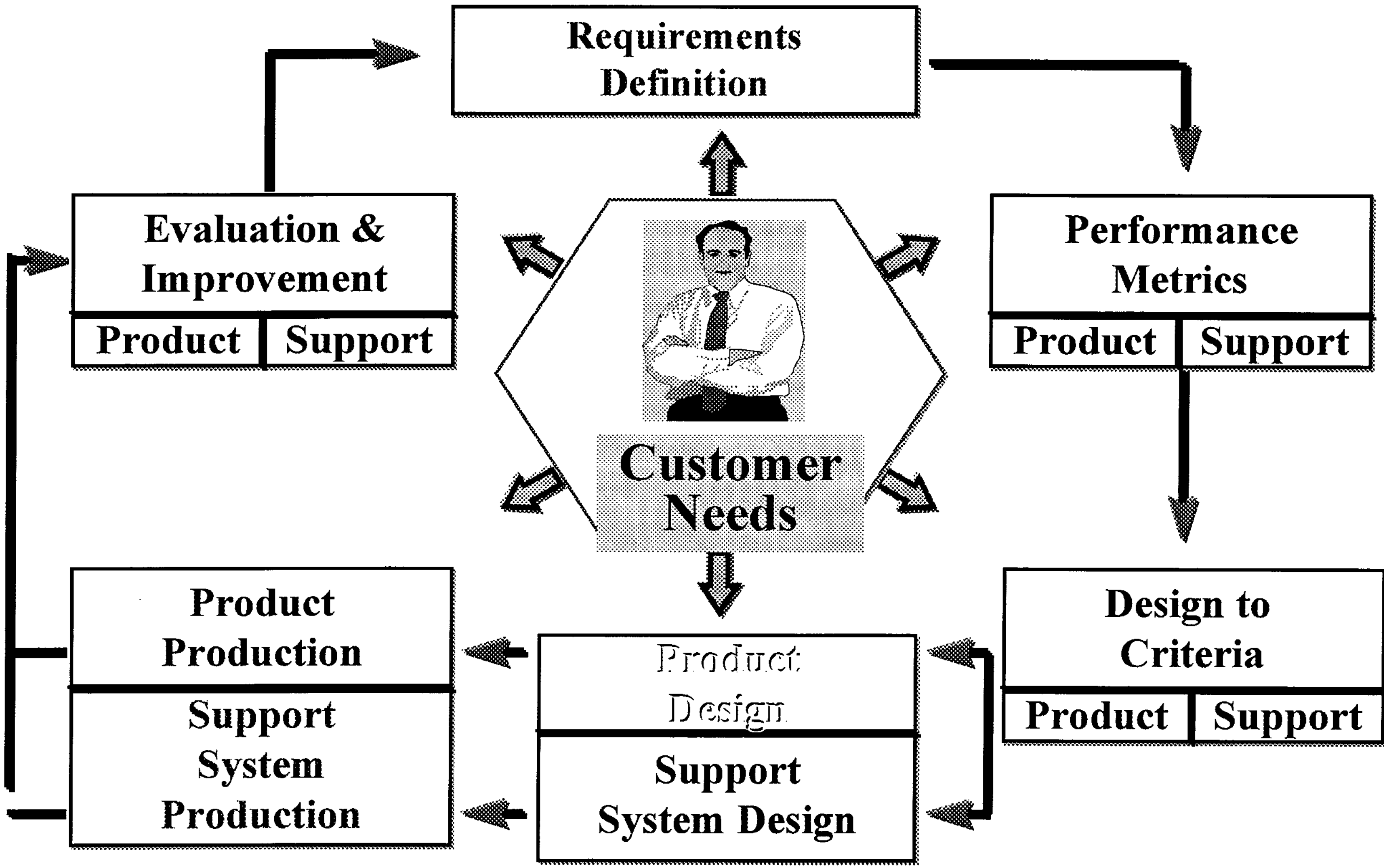
PERFORMANCE BASED SUPPORTABILITY
(A Concurrent Engineering Process)



Supportability is Designed In Not Analyzed In

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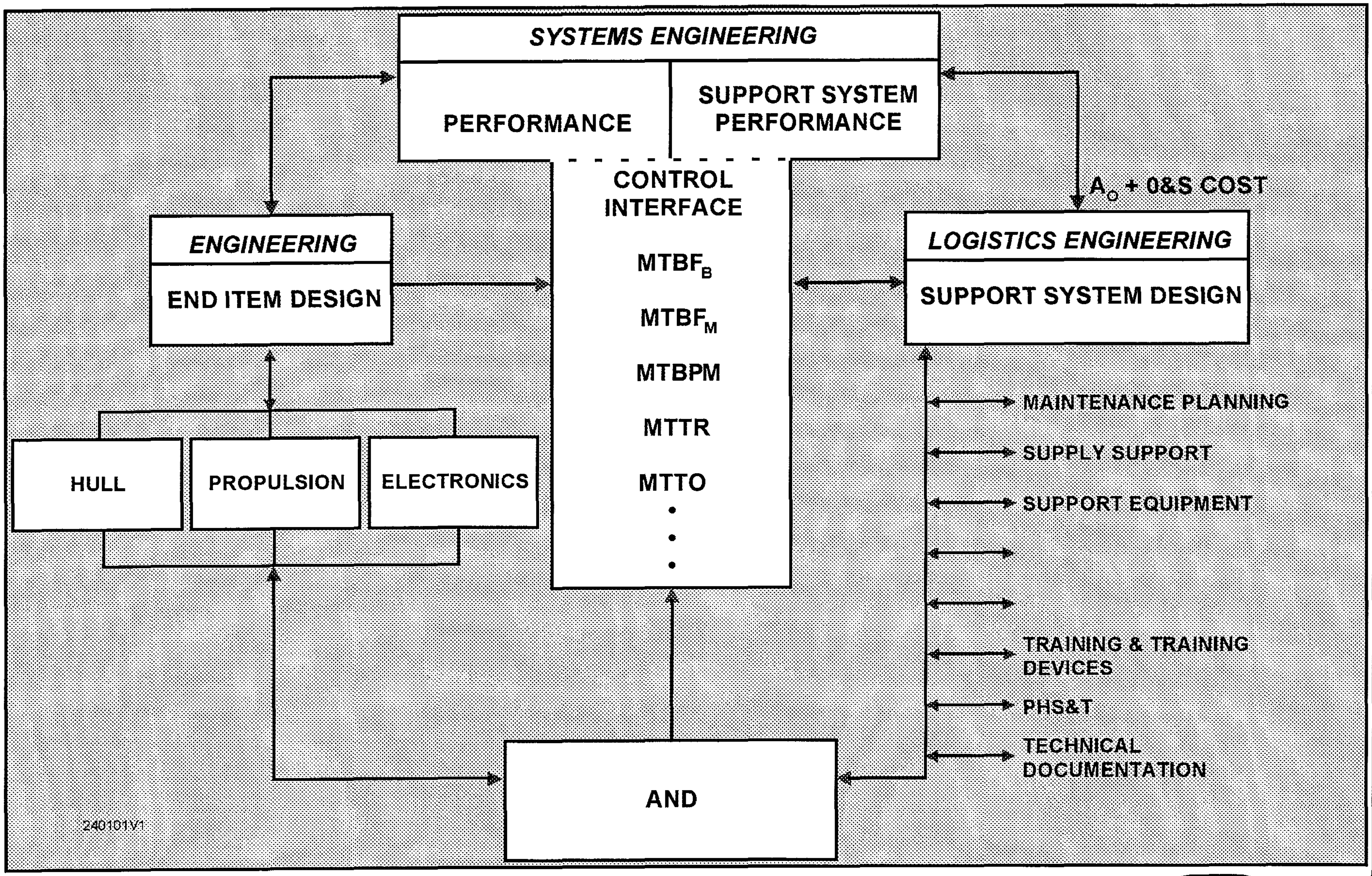
PERFORMANCE BASED DESIGN, A CLOSED LOOP SYSTEM



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SIX STEPS OF PBS

6. Continual Improvement
5. Acquire and Operate Support
4. Design Support Capability
3. Control Design Parameters
2. Determine Design Parameter Support Metrics
1. Define Operational Supportability Requirements

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Sample Program

Communication Management System

- Completed Steps 1, 2, & 3
- Determined O&S Cost Drivers
  - Operator Manpower & Training - 74% of O&S Cost
- Established Design Requirements to Control
- O&S Cost
  - Operator Manpower $\leq$ \$3.3 M (over 25 years)
  - Operator Training $\leq$ \$700 K (over 25 years)
- Converted Design Requirements to Design Parameters
- Expected Cost Avoidance: More Than The System Cost

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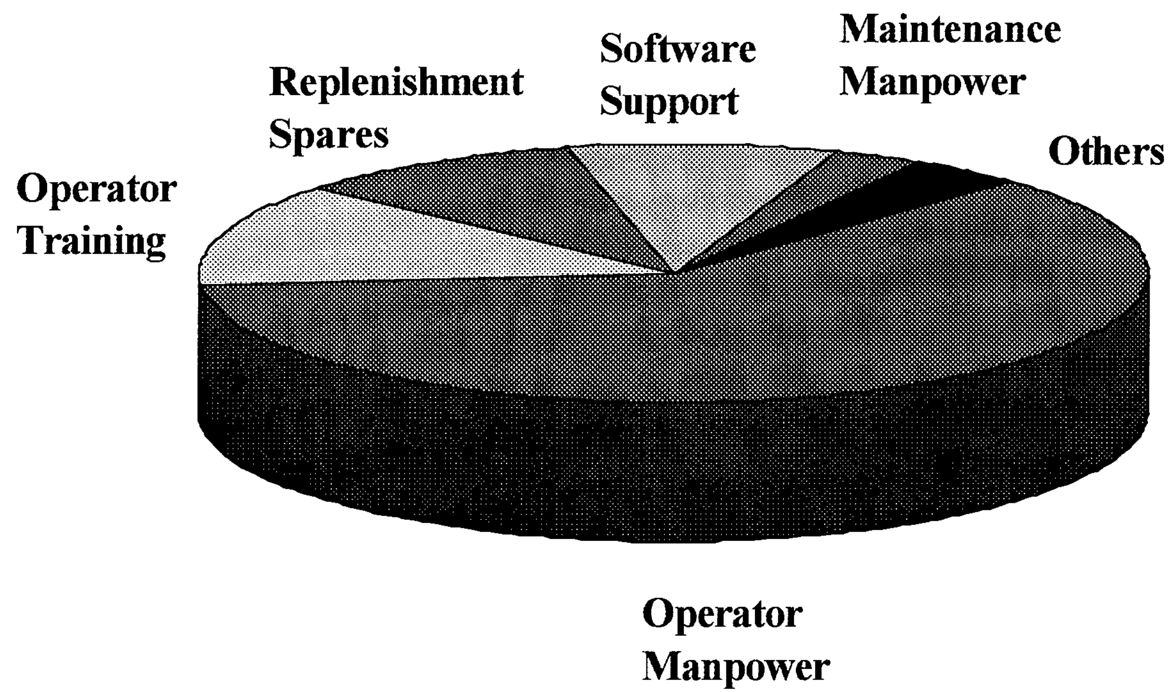
O&S Cost Distribution For Previous Item



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Communication Management System

Design & Support System

Design Parameters

PARAMETER	VALUE
Equipment Design Related:	
Mean Time to Operate Equipment (MTTOE)	12 seconds or less
Mean Time Between Maintenance Actions (Corrective)	800 aircraft flight hours or more
Mean Time to Repair (on A/C)	15 minutes or less
Mean Time to Repair (off A/C)	8 hours or less
Preventive Maintenance Requirements	None
Testability/Built-In Test	Refer to Supplier SOW para. 9.7-9.8
Support System Related:	
Remoteness from Maintenance	15 minutes or less
Spares Fill Rate	95%
Mean Time To Obtain Spares 1st Line	15 Minutes or less
Mean Time To Obtain Spares 2nd Line	6 hours or less
Operator Trainig Course Duration	4 hours or less

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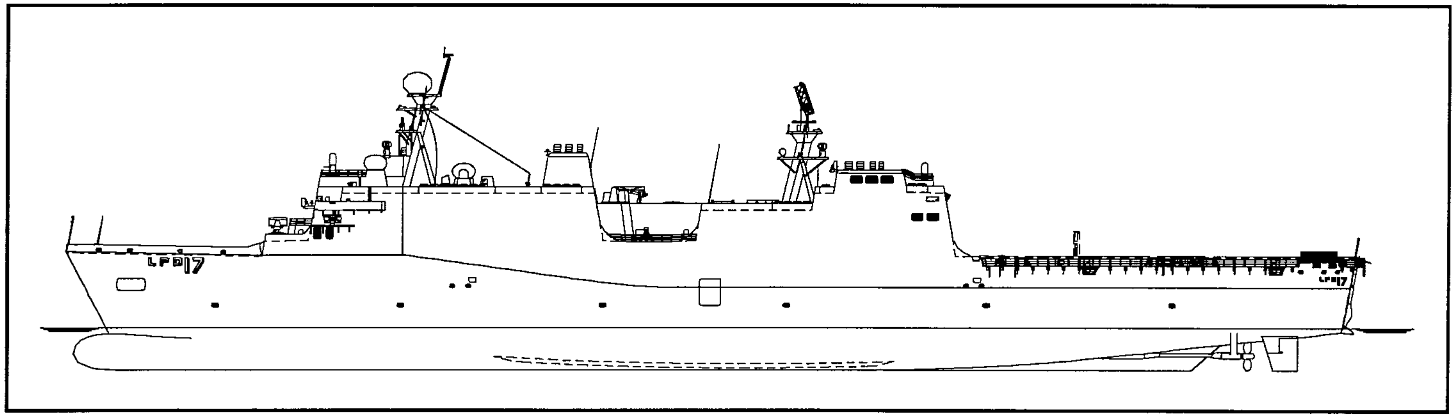
Sample Program

Marine Amphibious Assault Vessel



- Proposal Phase PBS - Steps 1, 2, & 3
- Selected Suppliers Based on Equipment Performance Against Established Design Criteria
- Developed a System With a 40% Reduction in the Cost-of-Ownership

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WHAT WE NEED TO MAKE IT WORK

- Train Senior Managers on potential for cost of ownership reductions through PBS
- Train Systems and Design Engineers on how to utilize PBS effectively
- Train Logistics Engineers on how to effectively operate in a concurrent engineering environment

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SOLE PBS TRAINING PROGRAMS

- 1/2-day session for executives
  - (What PBS is all about)
- 3-day session for technical managers
  - (How to put PBS to work)
- 5-day session for engineers and product support teams
  - (How to apply PBS to specific programs)

For details, contact Katherine O'Dea at SOLE home office (301) 459-8446 or e-mail solehq@aol.com

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SUPPORTABILITY STANDARD DEVELOPMENT

- Objectives
- Approach
- Implementation

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SUPPORTABILITY STANDARD OBJECTIVES

- Define supportability, its metrics and means of evaluation or measurement
- Enhance supportability communications between buyer and seller
- Enhance communication across segments of commerce

The Standard must add value to products or processes

A L E

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STANDARD DEVELOPMENT APPROACH

- **Keep it:**
  - Simple
  - Aligned with ISO criteria
  - Performance based
  - Industry-wide
  - Current with technology and business

A L E

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IMPLEMENTATION

- Work within SAE G-11 Supportability Committee
- Solicit industry and government inputs
- Develop a draft Standard
- Encourage use and comment
- Formalize the Standard

The Standard must capitalize on Best Industry Practices

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TRW

RePLACE™

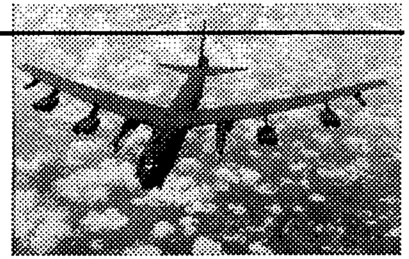
Reconfigurable
Processor for
Legacy
Avionics
Code
Execution

A Software Solution for Legacy System Upgrades

Mike Cook
Avionics Systems Division
Space & Electronics Group

TRW

Today's Situation



- Key military aviation areas of concern
  - Aircraft procurements down, force structure reduced
  - Existing and older technology is being forced to meet new requirements
  - Current avionics pressed to keep pace with requirements

- **Fewer people doing more with outdated systems**

- Existing avionics need improvements to:
  - Keep mission capable A/C flying longer at reduced cost
  - Solve parts obsolescence problems
  - Meet new/changing mission requirements

Software re-write is a major cost and risk factor

What Can Be Done? - *A Cost Effective, Lower Risk Approach to Avionics Upgrades*

TRW

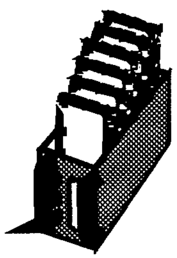
Reconfigurable Processor for Legacy Avionics Code Execution

RePLACE™ The Enabling Technology

Modernize + Maintain Capability + Add functionality

Change the H/W

Form - Fit - Function COTS replacement



- Capitalize on technology advances
- Replace current obsolete HW with open system standards

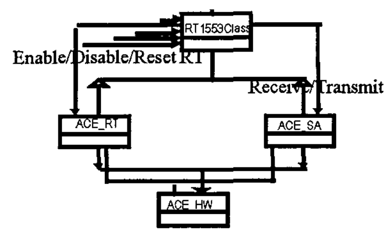
Save the Software

Current (Legacy) Operational Flight Program SW Code

- Preserve investment
- Set baseline for future enhancements

New Software

New Functions added to the Operational Flight Program SW Code in C++-ADA



- Incrementally add capability
- Rapid deployment
- Managed change, less risk

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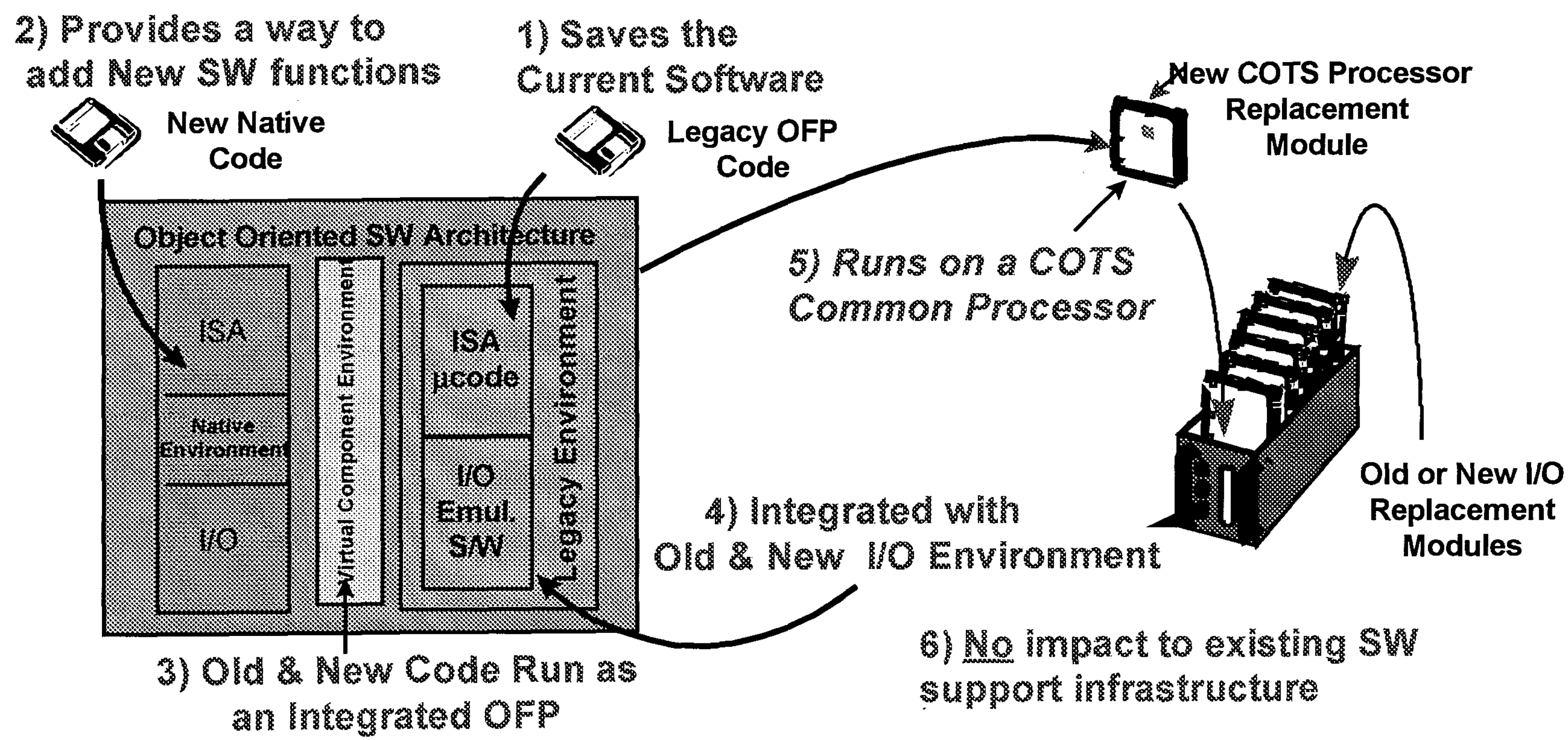
RePLACE™ - a Software Technology

TRW

RePLACE™ is an <u>Object Oriented Software Emulation Technology</u> that ---



6) <u>No</u> impact to existing SW support infrastructure

7) On-board RTNI monitoring

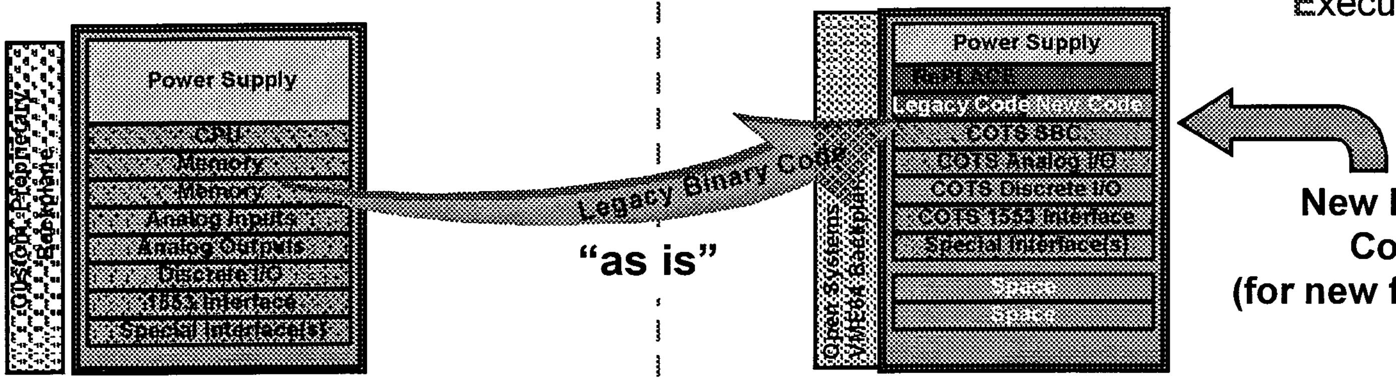
RePLACE™ - the Technology

TRW

Reconfigurable
Processor for
Legacy
Avionics
Code
Execution

Current Legacy Embedded Computer

New Replacement



"as is"

New Native Code (for new functions)

Custom hardware & backplane

Obsolete 16 bit instruction set

Little or no modern HOL support

Max'd out throughput & memory

No real-time monitoring

Low cost COTS, Open Systems

Runs *both legacy ISA & new 32/64 bit ISA*

Compatible with Ada95 & C++

***Faster* & more memory!**

Powerful real-time, non-intrusive monitoring capabilities

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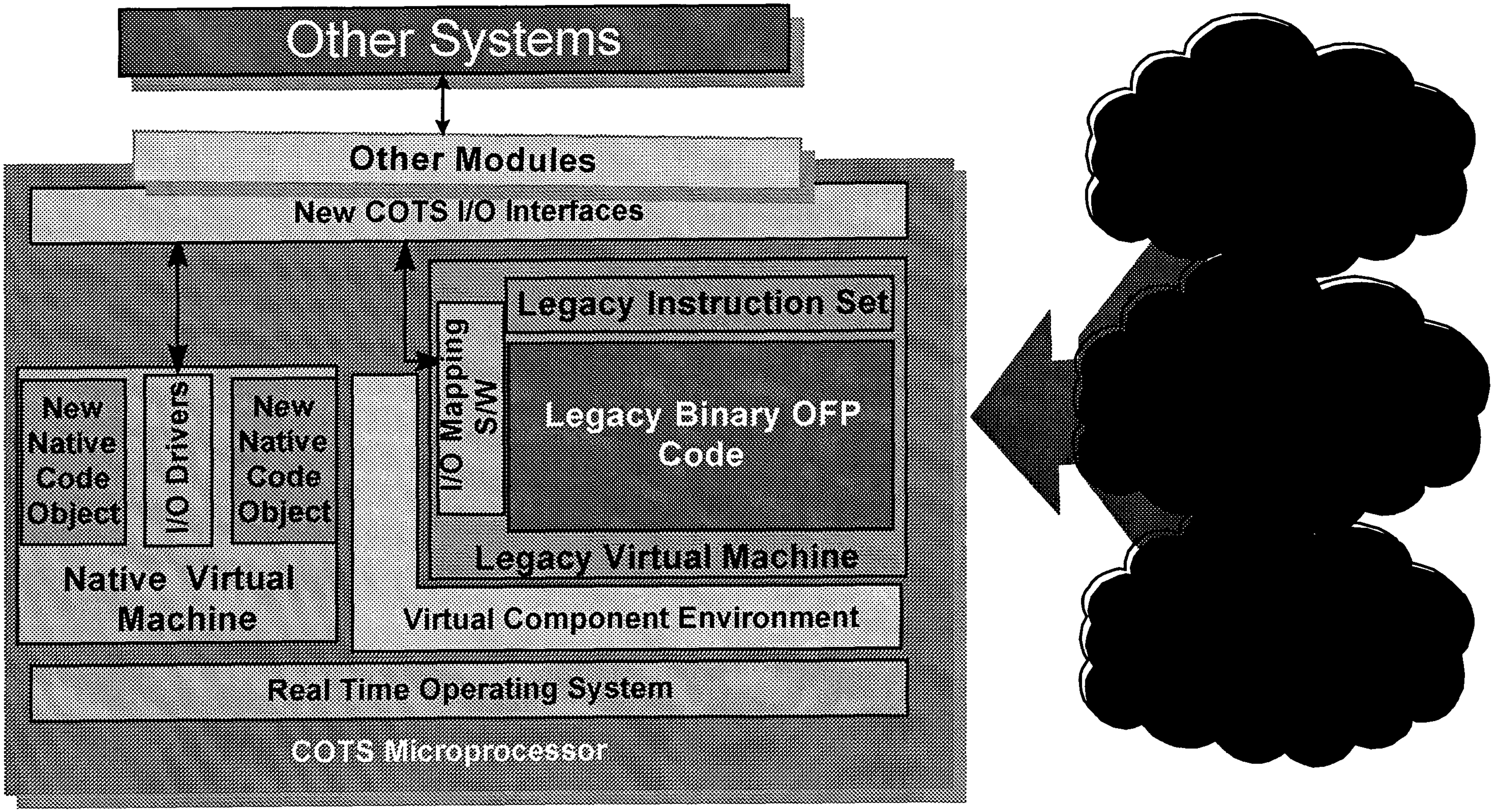
RePLACE™ Approach - Software View

TRW



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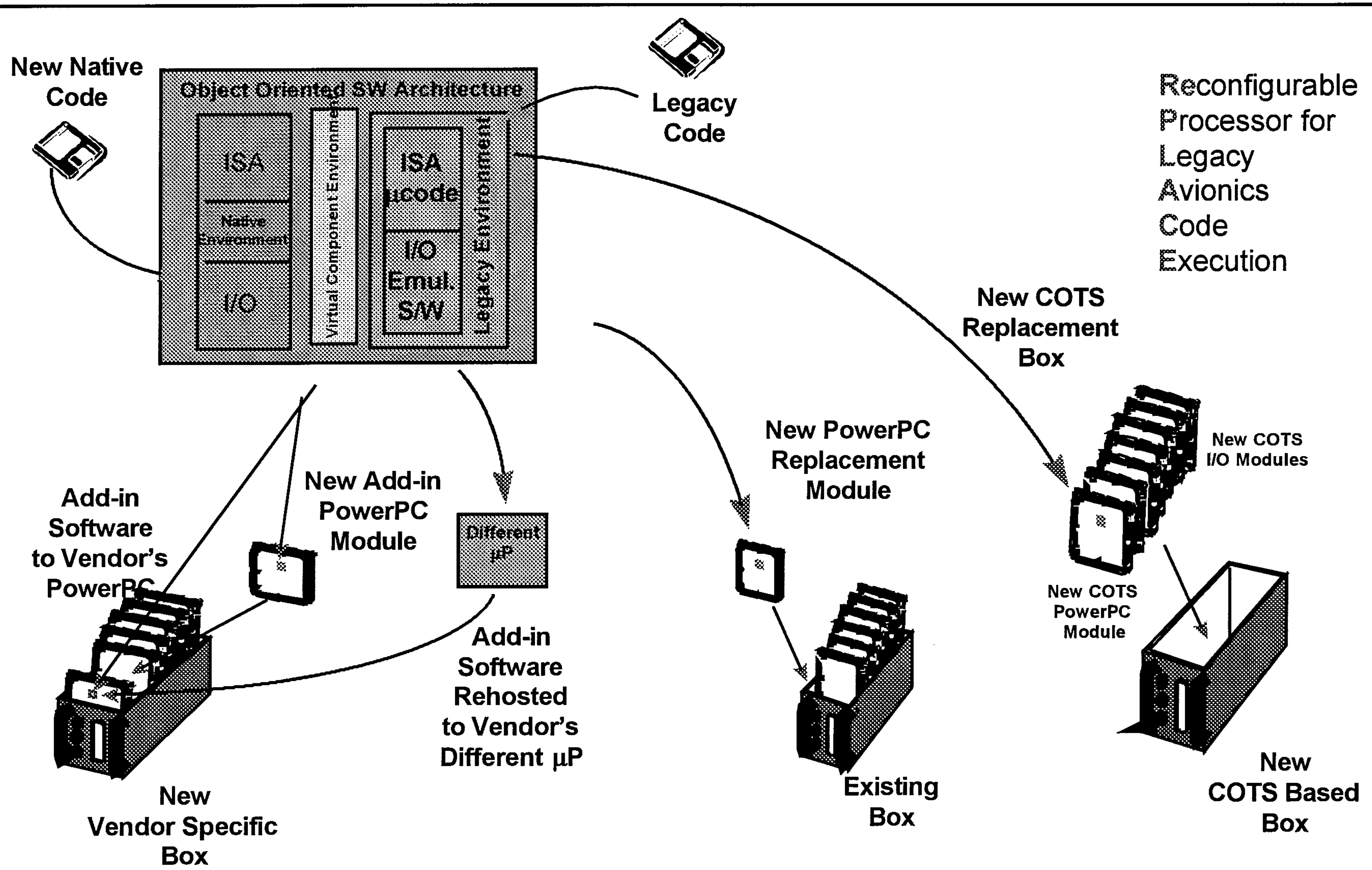
Upgrade Strategies with RePLACE™

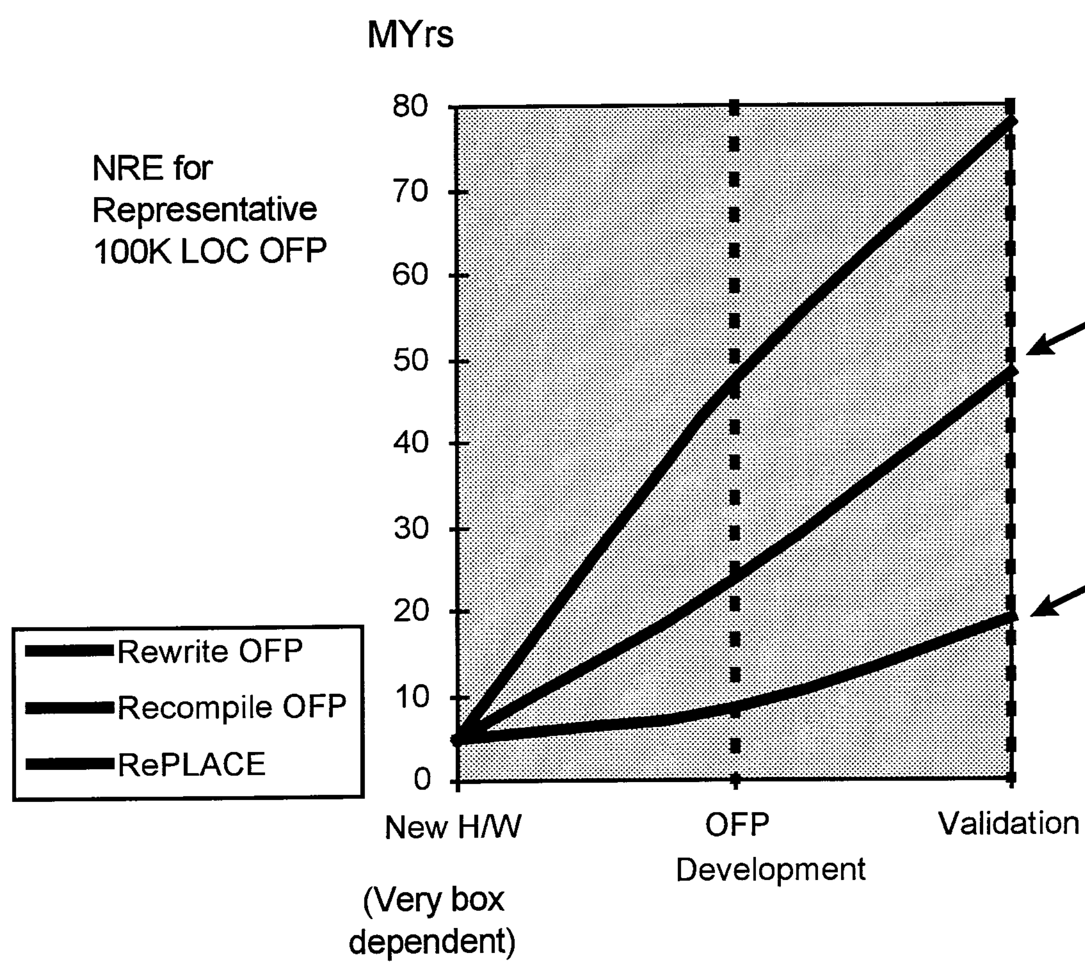
TRW

Reconfigurable Processor for Legacy Avionics Code Execution



Comparing RePLACE™ to Other Upgrade Strategies

TRW



- ***Tools are available to perform this tradeoff for different opportunities.***

Must address
- **Machine Dependencies**
- **Tool Maturity**

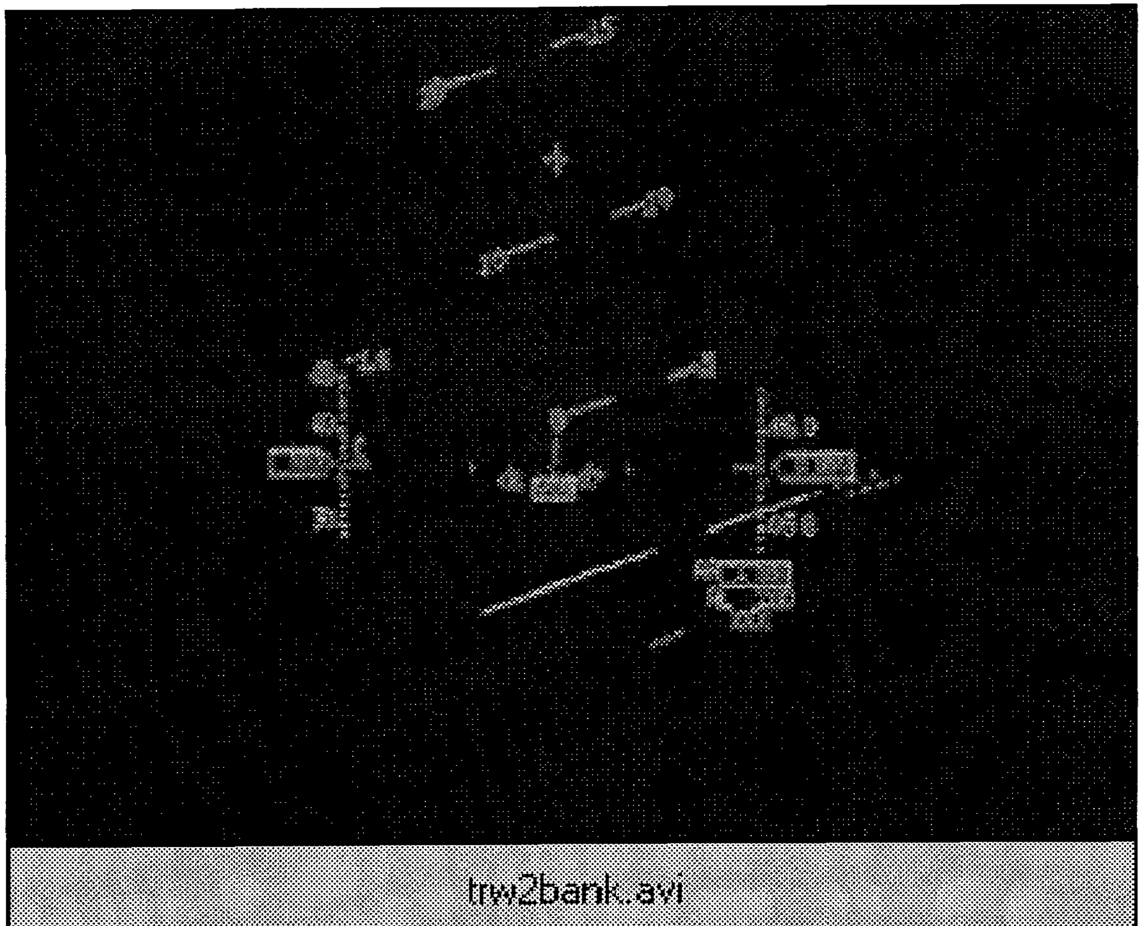
And...
- **Incremental upgrades difficult**

Takes advantage of
- **Existing test plans and procedures**
- **Testing at the black box level**

TRW

RePLACE™ Executing F-16 HUD OFP

Here's an example during a banking turn



- Runs binary OFP unmodified
- 10 X Improvement in throughput (10 Mips vs 1 Mip)
- Full 1750A Notice 1 implementation
- Instruction set validation completed using AF SEAFAC ATP & VSW
-

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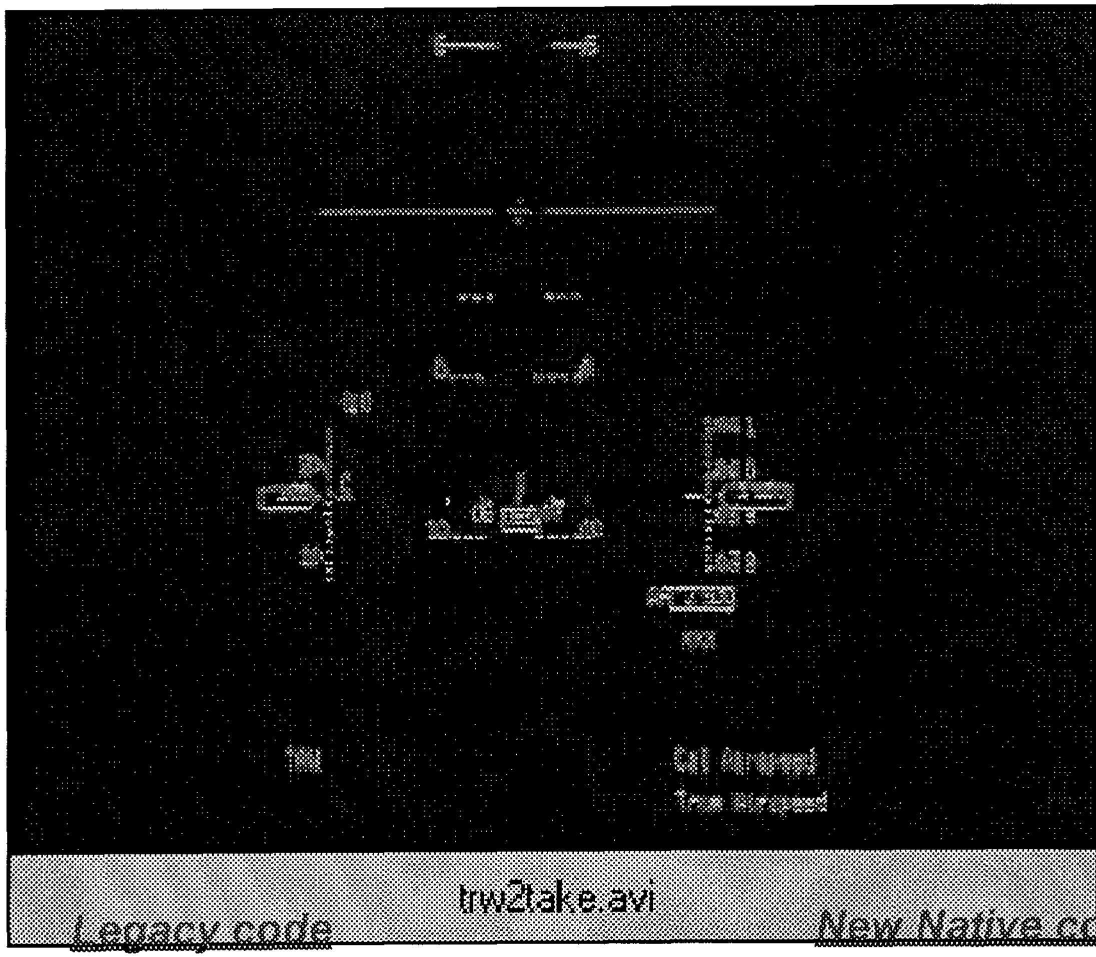
RePLACE™ Executing F-16 HUD OFP with New C++ Code Running Concurrently

TRW

Running concurrently

Sharing data



Legacy code

- Jovial & assembly code
- Compiled & linked for a MIL-STD-1750A

New Native code

- C++ code
- Compiled for a Power PC

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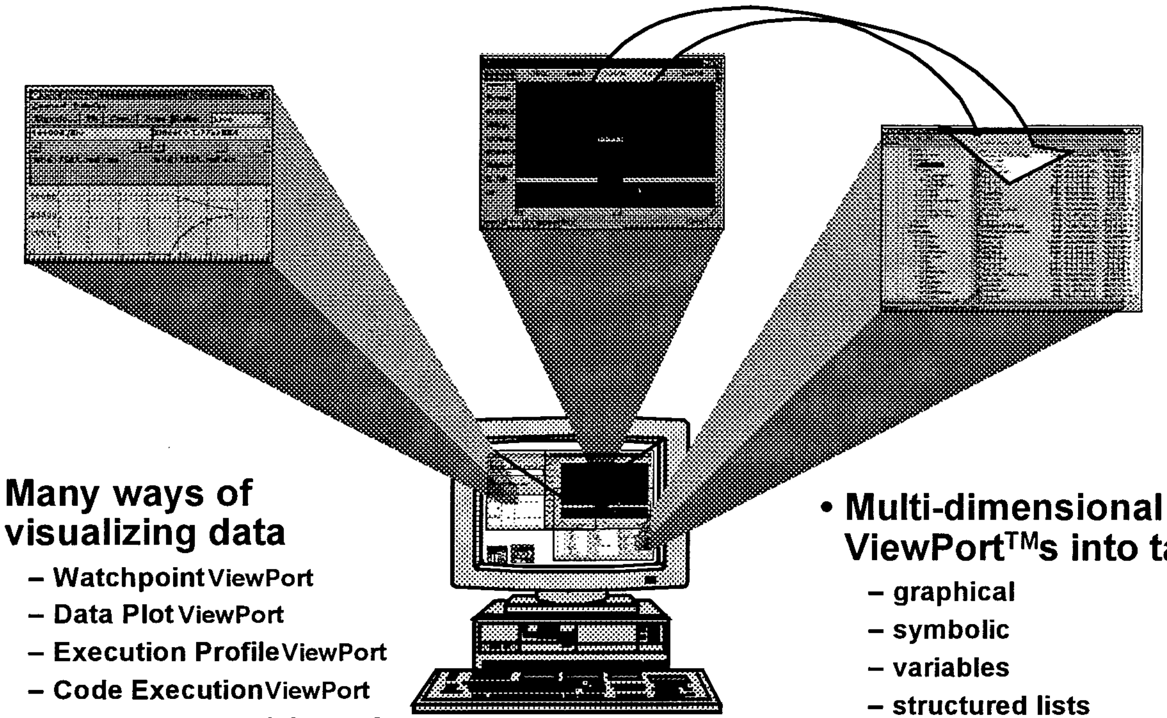
TRW

VIEWstation™ Software Support Toolset

Portable, extensible, web-enabled set of Java Applets



- **Many ways of visualizing data**
  - Watchpoint ViewPort
  - Data Plot ViewPort
  - Execution Profile ViewPort
  - Code Execution ViewPort
  - Export to spreadsheets & 3rd party tools

- **Intuitive Desktop Paradigms**
  - drag & drop
  - "Explorer"-like multi-pane displays

- **Multi-dimensional ViewPort™s into target**
  - graphical
  - symbolic
  - variables
  - structured lists
  - objects
  - messages
  - queues
  - execution events
  - performance
  - source & ass'y code flow

- **Applets include:**
  - **VIEWmaster™** for session, event, and View specification & control
  - **BullsEye™** debug manager for control of interactive & scripted debug sessions
  - **EagleEye™** real-time monitoring & analysis manager
  - **CruiseMaster™** symbol browser & editor for interactive & automated symbol database exploring, query & control
  - **MixMaster™** RePLACE™ DISC configurator for interfacing native code objects to legacy OFP object(s)
  -

Application Summary

TRW

RePLACE A cost effective solution

- **Lower development cost**
  - Reuses existing software (Preserves original investment)
  - Reduces regression testing
  - Establishes known good starting point for managed software upgrades
  - Supports incremental funding profiles
- **Lower sustainment cost**
  - Takes advantage of COTS-based, open systems hardware
  - Allows for migration path to modern software development environment
  - Offers software and system diagnostics through RTNI monitoring

Enables Affordable Avionics Upgrades

This Technology is Ready to Apply Today

12/1/98

Data: Long-Term Supportability

NDIA 1st Annual
Systems Engineering and Supportability Workshop
September 15-17, 1998
San Diego, California

Carol J. Gutierrez
Principal Systems Engineer
email: gutierr@alc.com

Ascent Logic Corporation
San Jose, California 95134

Agenda

- Why Should A Program Manager Worry About Data and Tools to Store It Anyway?
  - What is Data?
  - What is Information?
  - From Data to Information…
- As You Plan, Consider
  - Example of Data and Information Needed for EIA 632 Requirements Management
  - Life Cycle Example for Process Enabler Tools and Interfaces
- Conclusions and Recommendations

What is Data? What is Information?

Data

- The raw materials from which information is developed

EXAMPLE:

- A single "SHALL" statement
- A test result
- A specification change page

Information

- Data that has been transformed into a meaningful form for the user (customer, recipient)
-

EXAMPLE:

- A specification with many "SHALL" statements
- A test report
- An impact analysis of the results of a change

Data to One is... Information for Another

Program Managers Need Quality Data and Enabling Tools to...

- Develop appropriate information at the right time to help manage (minimize, mitigate) risk
- Build cooperation (trust) to get the job done more efficiently and effectively
  - Customers
  - Users
  - Team members
- Understand
  - Impacts to changes in requirements
  - Decisions, issues, and rationale

To Move from Data to Information...

- Plan the Program's Process Needs
- Determine Basic Data Requirements
- Identify Information Products to meet Programmatic Goals
  - Define Characteristics of Information Products
  - Define Quality Requirements of Information Products
- Define "Information Manufacturing System"
  - Identify Tools Required to Store Data
  - Identify Software Needed to Produce Information Products

What is this Concept of Total Data Quality Management?

- Quality data is fit for use ? concept of data quality is relative and depends on the receiver of the data and information
- Make data and information meet the "fit for use criteria" which implies more than "just being accurate"

Taken from: Communications of the ACM; Feb 1998, Vol. 41, No. 2 , pp 58–65

Define Quality Requirements of Information Products

- **Contextual**
  - Relevancy
  - Value-Added
  - Timeliness
  - Completeness
  - Amount of data
- **Representational**
  - Interpretability
  - Ease of Understanding
  - Concise
  - Consistent
- **Intrinsic**
  - Accuracy
  - Objectivity
  - Believability
  - Reputation
- **Accessibility**
  - Access
  - Security

See Wang, Comm of the ACM, Feb 98/ Vol. 41, No. 2; pp 58-65

As You Plan, Consider…

Information Databases

Importance of data re-use

The entire life cycle…

What you need to plan

Tools required

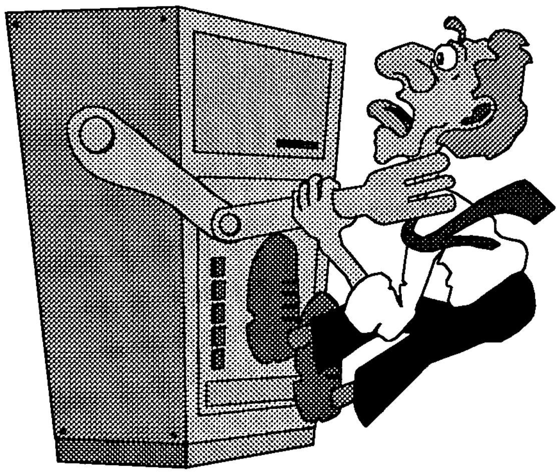
Information Databases

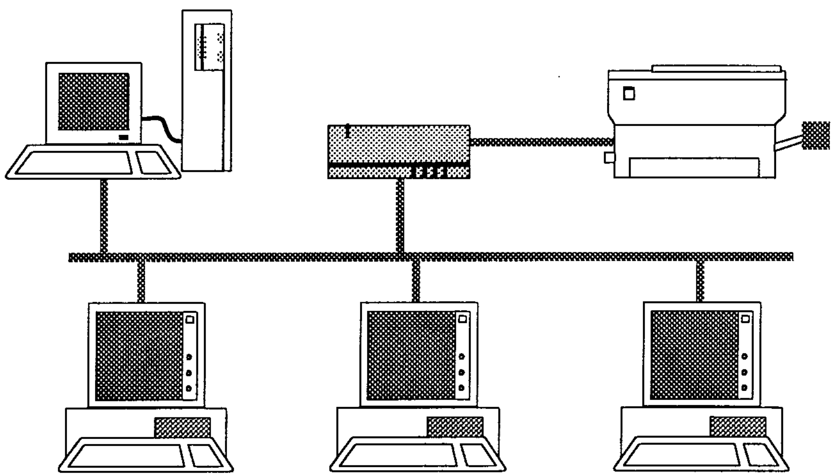
- A repository that provides a capacity to maintain work products and outcomes from implementation of the processes for engineering a system in a controlled manner.
  - Provides the basis for controlled maintenance of the information needed by the multidisciplinary teams and management to efficiently and effectively accomplish their assigned tasks.

- Contains the requirements, configurations of a system (past, current, and planned), and all analyses and test results.
  - Allows for traceability
  - Supports the validation and verification tasks
  - Is essential for change management
  - Provides information to support decision making

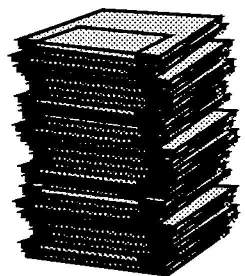
- Term "Information Database" used 40 times
- Found in 16 of 33 Requirements
- Applies throughout Life Cycle

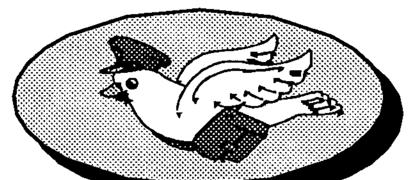
Information Database and EIA 632 Tasks (1 of 5)



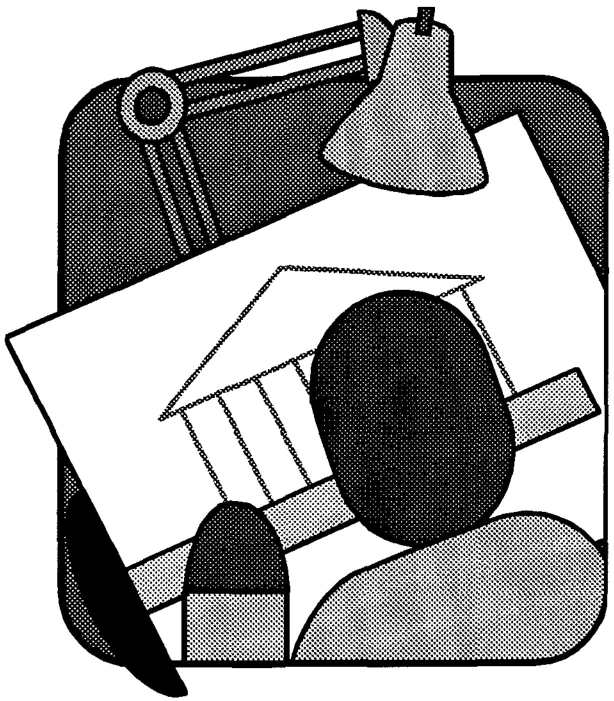


- **Establish Database**
  - Requirement 5: task b
- **Capture Appropriate Data**
  - Requirement 12: task a
- **Manage Database**
  - Requirement 12: task g
- **Disseminate Information**
  - Requirement 13: (implied in all tasks)





Information Database and EIA 632 Tasks (2 of 5)

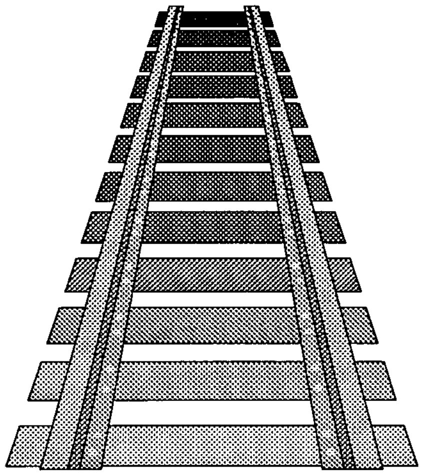


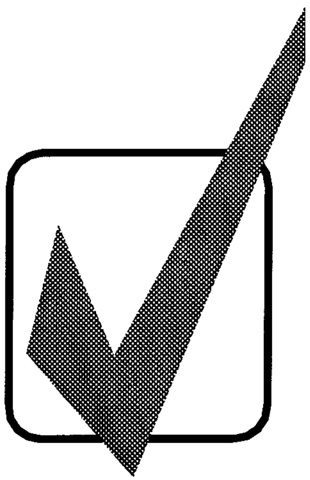
- Validated System Technical Requirements
  - Requirement 16: task i
- Logical Solution Representations & Set of Validated Derived Requirements
  - Requirement 17: task f
- Design Solution Work Products (include key decisions, rationale, results of tradeoff analyses, assumptions)
  - Requirement 19: task d

Information Database and EIA 632 Tasks (3 of 5)

- Effectiveness Analyses
  - Requirement 22: task f
- Outcomes of Tradeoff Analyses
  - Requirement 23: task c
- Outcomes of Risk Analyses
  - Requirement 24: task f

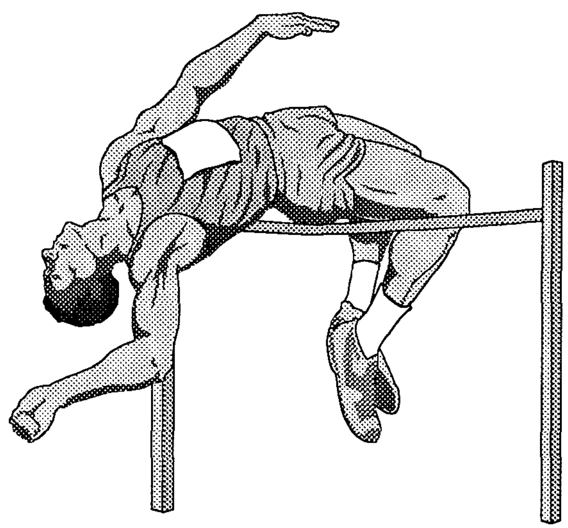
Information Database and EIA 632 Tasks (4 of 5)





- Validation Results
  - Acquirer Requirements
    - Requirement 26: task e
  - Other Stakeholder Requirements
    - Requirement 27: task e
  - System Technical Requirements
    - Requirement 28: task h
  - Logical Solution Representations
    - Requirement 29: task g
  - End Product
    - Requirement 33: task e

Information Database and EIA 632 Tasks (5 of 5)



- Verification Results
  - Design Solution
    - Requirement 30: task d
  - Delivered End Product
    - Requirement 31: task d
  - Readiness Demonstration for Enabling Products and Processes
    - Requirement 32: task d

Why Is Data Re-use So Important?

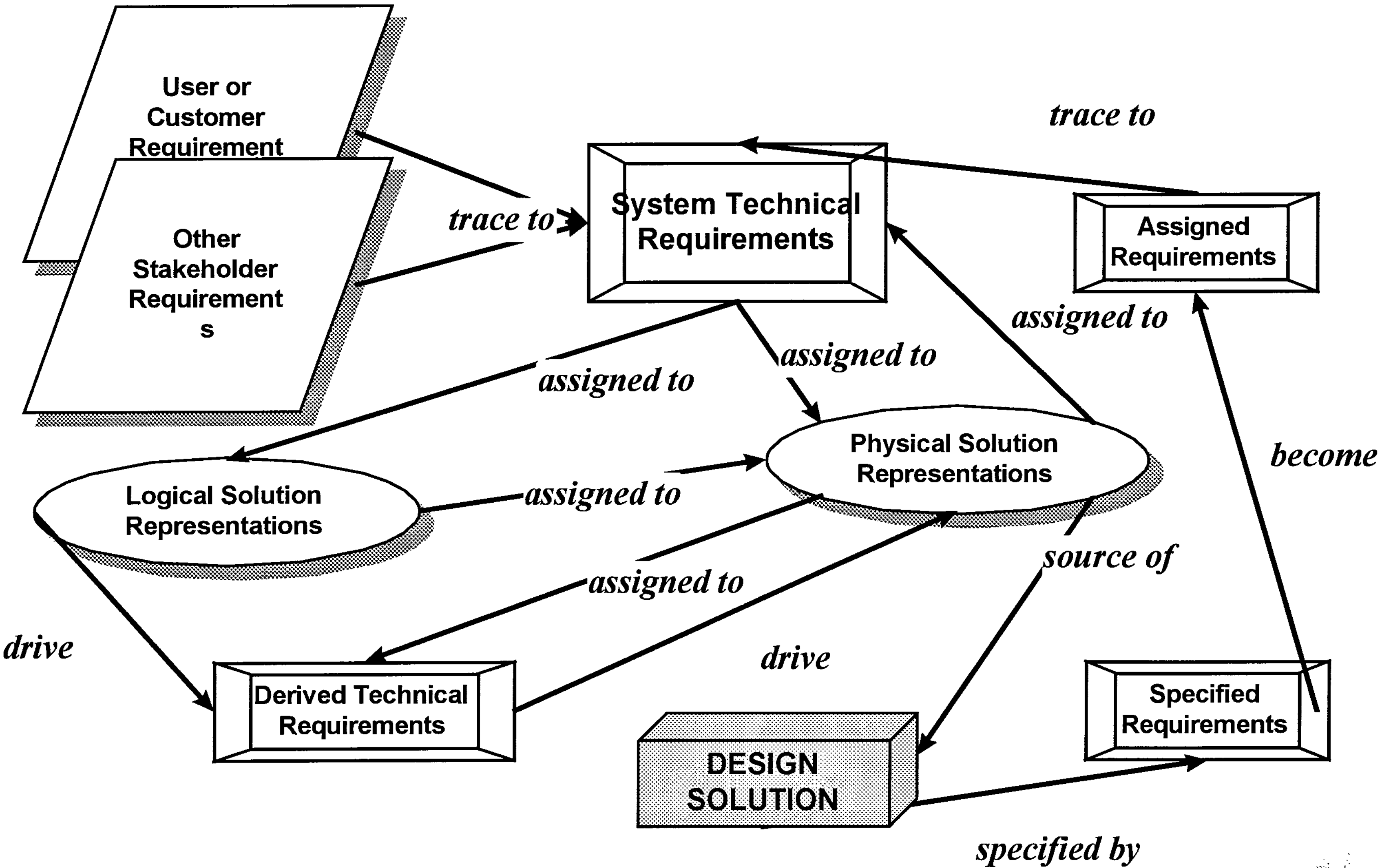
- **Minimize**
  - Maintenance costs
- **Maximize**
  - Data integrity
  - Data accuracy
- **Help**
  - Ensure timeliness of information delivery
  - Identify potential opportunity to reduce costs by reusing code or inventoried products

What To Do...

- **Identify:**
  - Information Products
  - Tools and Environment
  - Maintenance Resources
- **Define:**
  - Characteristics of Information Products
  - Quality Requirements of Information Products
  - "Manufacturing System" for production and maintenance of Information Products
- **Consider:**
  - Where data will be stored (what tool)
  - What stored data mean in your process (semantic meaning)
  - How will data be stored in the tool (schema)
  - Reduce storage of redundant data
  - Define data consolidation and change control process and procedures

Taken from: Communications of the ACM; Feb 1998, Vol. 41, No. 2 , pp 58–65

EIA 632 Requirements Management Semantics



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Process and Tool Enablers

Process Needs		Tool Selection Options 1	2	3	4	5	6
Control and Manage Changes		a	b, c	a, c	a, c	a, c	b
Report Status		z	b, c	z	a, c	a, c	a, z
Produce Deliverables		c	c, d	c	c	a, c	w
Develop Requirements		a, c	z	d, c	d, s, c	c	c
Develop Architecture	Logical	c	s	s, t, c	t, c	c	a
	Physical	c	f	z	c	c	c
	Interface	z	c	c	c	c	z
	Information	c	h	c	c, s	c, s	c
Develop Design		e, f	z	c	s, h, c	c	c
Implement Design		f	f	k	k, f	f	k
Verify Implementation		f, g	v	v	v, c	v	c
TOOLS REQUIRED		a, c, e, f, g, z	b, c, d, f, h, s, v, z	a, c, d, k, s, t, v, z	a, c, d, f, h, k, s, t, v	a, c, f, s, v	a, b, c, k, w, z

Option 5 Chosen

- Min. # of tools
- Reduced # of tools for each process step (need)
- All tools in this option have Public APIs; interfacing is easier
- Tool "c" appears to be capable of covering many of the process steps (needs); assume Tool "c" has internal integration to move from one process step to another.
- Tool "c" has CAIV solution
- Tool vendors "c" and "a" have consultants to help define software interfaces
- Tool "c" vendor has resources to help develop interfacing software

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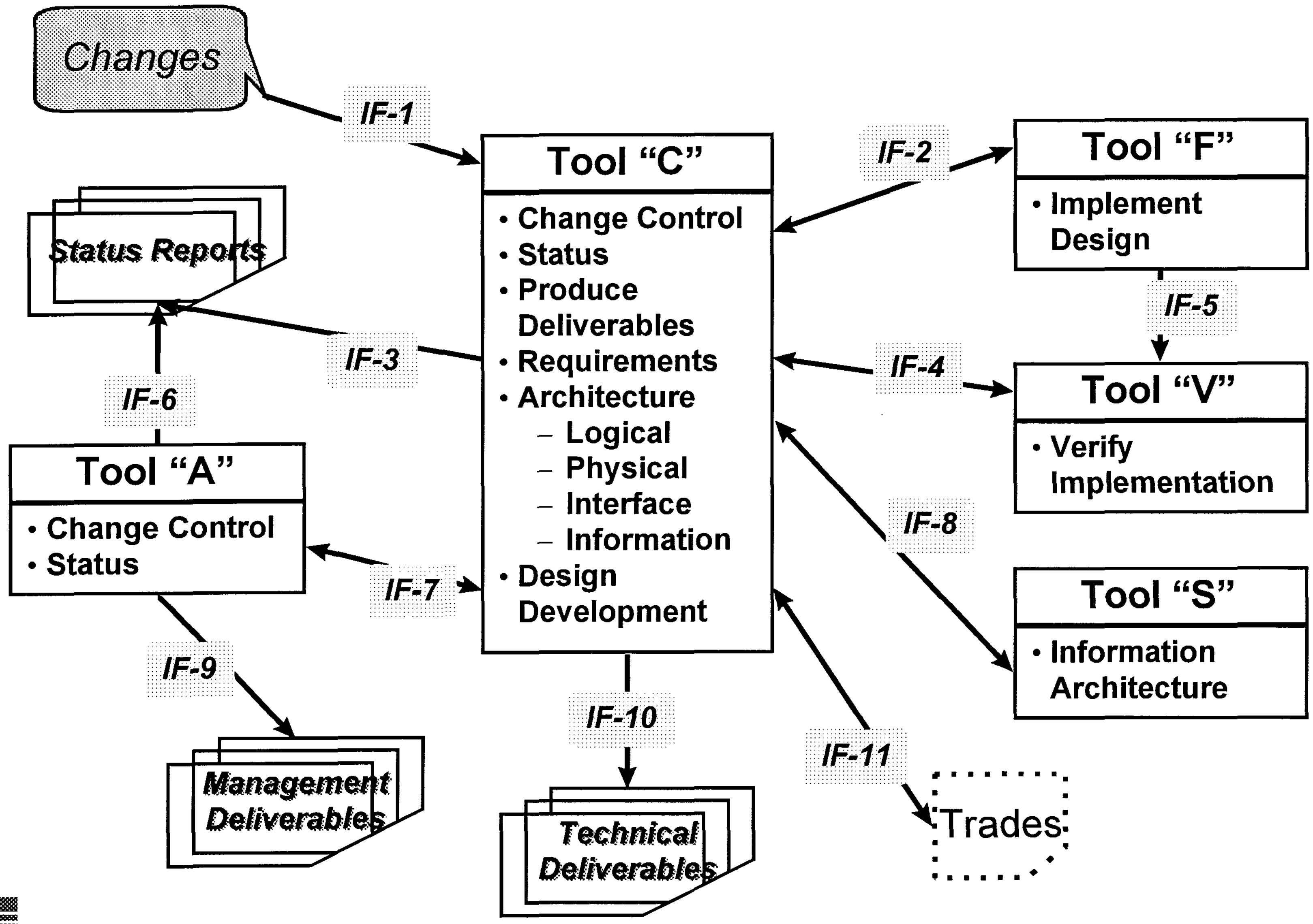
Tool Interfaces



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Tool Costs (Initial + Maintenance) in $000s

Tool	Num. Seats	List		Maintenance			Projected Cost (w/o Discount)
		Seat	Total	15% /yr	Dev (Yr 2 -6)	Ops (Yr 7-30)	
A	5	70	350	52.5	262.5	252	864.5
C-1 (re)	200	3	600	90	450	2160	3210
C-2 (rm)	40	8	320	48	240	1152	1712
C-3 (api)	45	2	90	13.5	67.5	324	481.5
C-4 (exc)	10	15	150	22.5	112.5	540	802.5
C-5 (sa)	10	19	190	28.5	142.5	681.6	1014.1
C-6 (sd)	5	50	250	37.5	187.5	900	1337.5
F	10	50	500	75	375	1800	2675
V	5	200	1000	150	750	3600	5350
S	3	50	150	22.5	112.5	108	370.5
			3600	540	2700	11517.6	17817.6

Assumes:
- 30 year Program Life; 6 year Development; 300 Engineers during Development; all Engineers and Managers need easy access to the Information Database
- Maintenance starts Year 2
- No. of seats for maintenance reduced to 1/5th after Development

Tool Interfaces Costs (in Months)

Inter-face	Type	Tools	Develop Cost (Mo.)	Maintain Cost (Mo.)	Projected Cost (Mo.)	Projected Cost ($000s)
IF-1	Uni (Ext)	→ C	3 x .25	360 x .01	4.35	87
IF-2	Bi (Int)	C ←→ F	3 x 1.5	360 x .1	40.5	810
IF-3	Uni (Int)	C → Rpt	3 x .25	360 x .01	4.35	87
IF-4	Bi (Int)	C ←→ V	3 x 2	360 x .1	42	840
IF-5	Uni (Int)	F ←→ V	3 x 1	360 x .01	6.6	132
IF-6	Uni (Int)	C → Rpt	3 x .25	360 x .01	4.35	87
IF-7	Bi (Int)	C ←→ A	3 x 2.5	360 x .5	181.5	3630
IF-8	Bi (Int)	C ←→ S	3 x 1.5	360 x .01	8.1	162
IF-9	Uni (Int)	C → Rpt	3 x 2	360 x .5	186	3720
IF-10	Uni (Int)	C → Rpt	3 x 1	360 x .5	181	3620
IF-11	Bi (Int)	C → Trades	3 x .25	360 x .5	180.75	3615
			35.5	810	845.5	16910

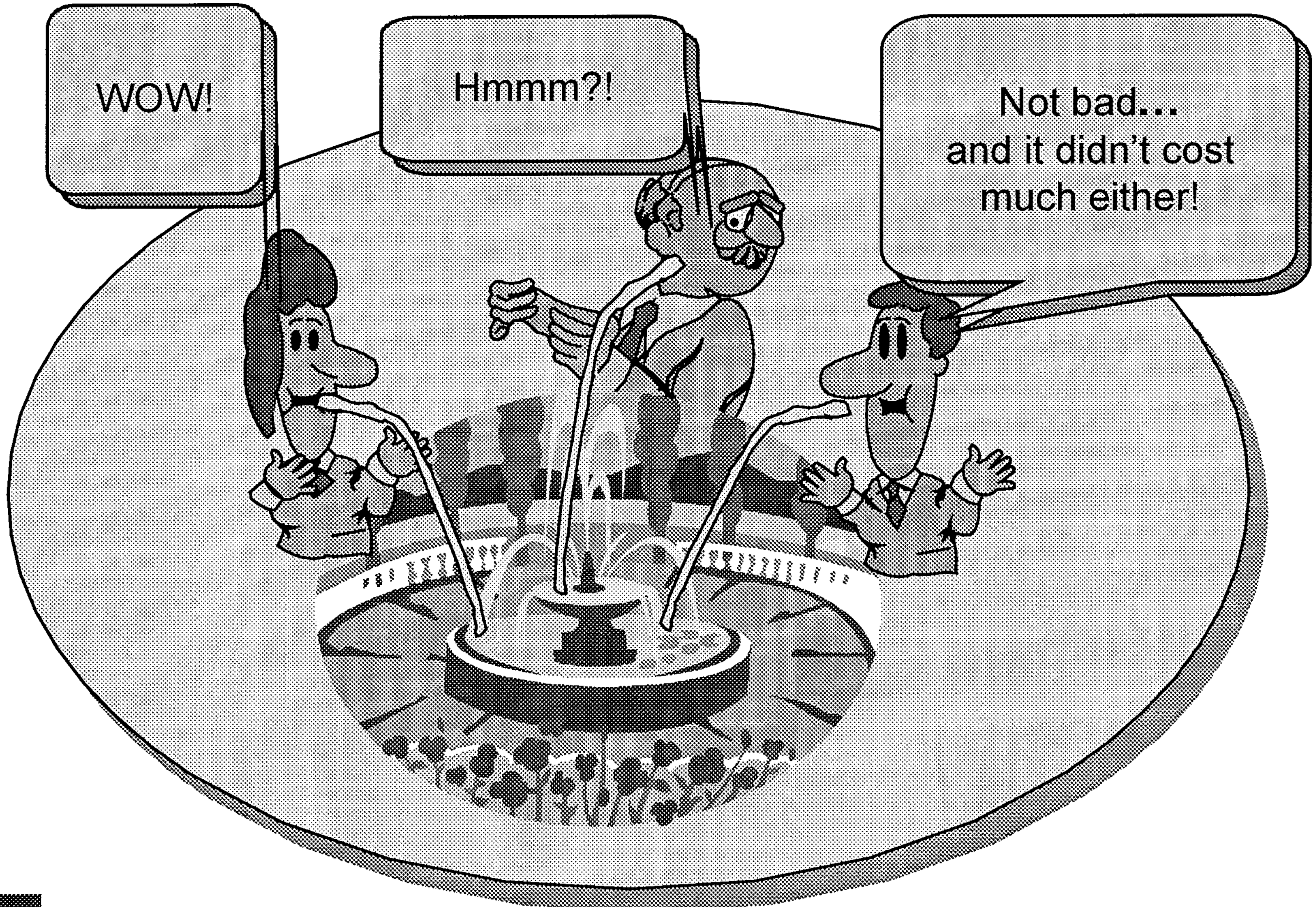
Assumes:
- 30 year Program Life; 6 year Development
- Optimistic Software Development Schedule
- Estimated 20 days/month; $1000/day consultant rate
- Minimal Schema changes (3 for each tool over Program Life)

Tools + Tool Interfaces Costs (Hypothetical 30 Year Program)

- Software, without Discount ($17,818K)
  - $3,600K Acquisition
  - $2,700K Development Maintenance
  - $11,518K Operational Maintenance
-
- Tools Interfaces ($16,910K)
  - $710K Development
  - $16,200K Maintenance (Development + Operations)

- Software, with 40% Discount ($ 10,691K)
  - $2,160K Acquisition
  - $1,620K Development Maintenance
  - $6,911K Operational Maintenance
-
- Tools Interfaces ($16,910K)
  - $710K Development
  - $16,200K Maintenance (Development + Operations)

Data and Information Re-Use



Summary: Data Quality and Information Integrity

- Need resources and planning to Establish and Maintain an Information Database
- Plan Information Product Needs for the Life Cycle
  - Data and Information are not the same
- Greater the number of tools needed to store the data, greater the chances of redundant data
  - Redundant data is a problem in data accuracy and data integrity
- Reduce number of tools needed to contain the data to support engineering process

Summary: Tools Purchase and Maintenance

- Initial tools purchase price is not the only life cycle cost
- Maintenance costs for tools mount up
  - Need to maintain bridges or other interfaces between the tools
    - Costs time and money
    - Increases possibility of data redundancy
  - Maintenance of tools interfaces is significant; special skills needed
    - Development: software
    - Administration: hardware and database
  - The more tools you have the more maintenance cost you have
    - ~10 - 18% of purchase price of tool, annually

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Summary: Initial Skill Sets Needed

Need someone who:

- Knows your engineering process
- Can facilitate a team in actualizing your process with the tools
  - Help in teambuilding
- Knows how to define and develop the software needed to exact and formulate information from data contained in the repository
  - Provide semantic mapping help
  - Develop automated user tools
  - Help define and detail a "users guide" for the tool set
- Knows the hardware side of setting up and maintaining data repositories

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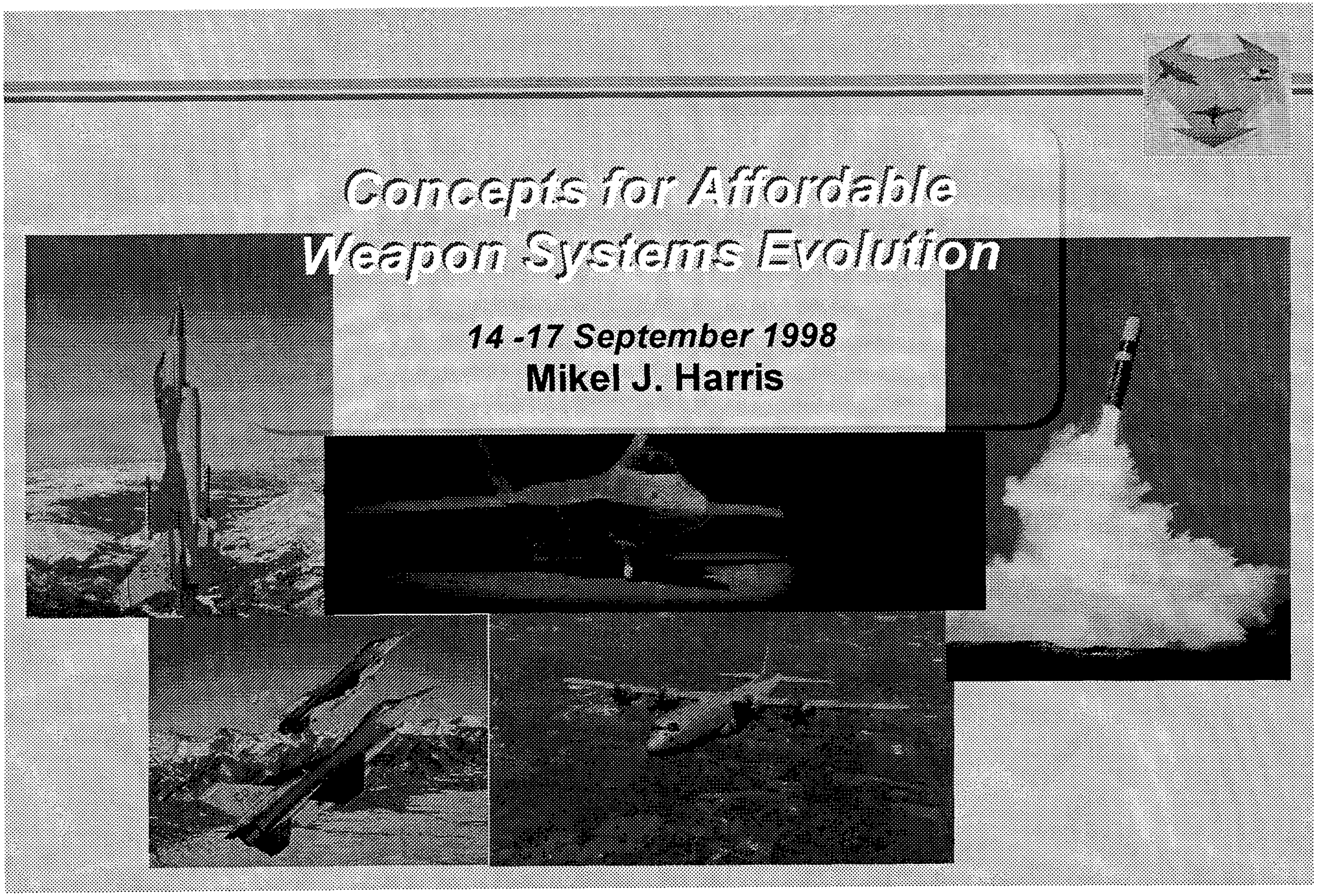

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A New Approach is Needed to Support Weapon Systems

Conceptual Approach ...

- **Institute the Commercial Acquisition Reform**
- **Revise Our Systems Engineering Process to Include Open Systems Approaches**
- **Measure and Monitor Weapon System Support**
- **Evolve the Weapon System Product, Continuously**
  - ✓ *Move From the Traditional Service Life Cycle Model to a Cyclic, Constant Cost Model for Major Weapon Systems*

The Goal ...

- **Reduce Total Cost of Ownership**
  - ✓ *Maintain Production Cost (~$20M) at Significantly Lower Production Rates (24 AC/mth to 4-8 AC/mth)*
- **Lower Support Cost, At Higher Levels of Performance**
  - ✓ *Measure the Process... (20% Added Savings)*
  - ✓ *Software Support (50% reduction since 1993, another 50% by 2000)*

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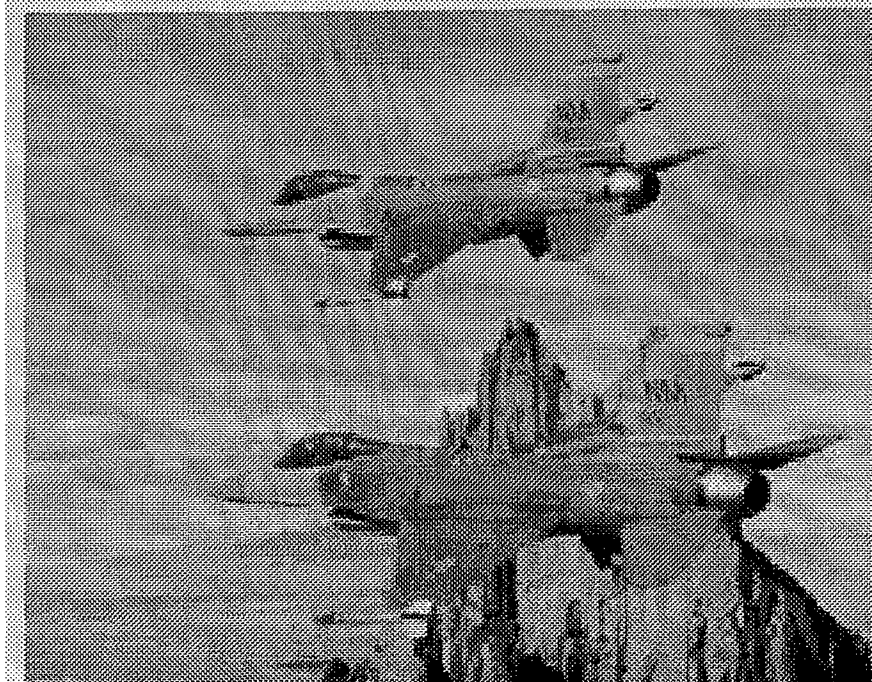
Commercial Acquisition:

Our Way of Doing Business



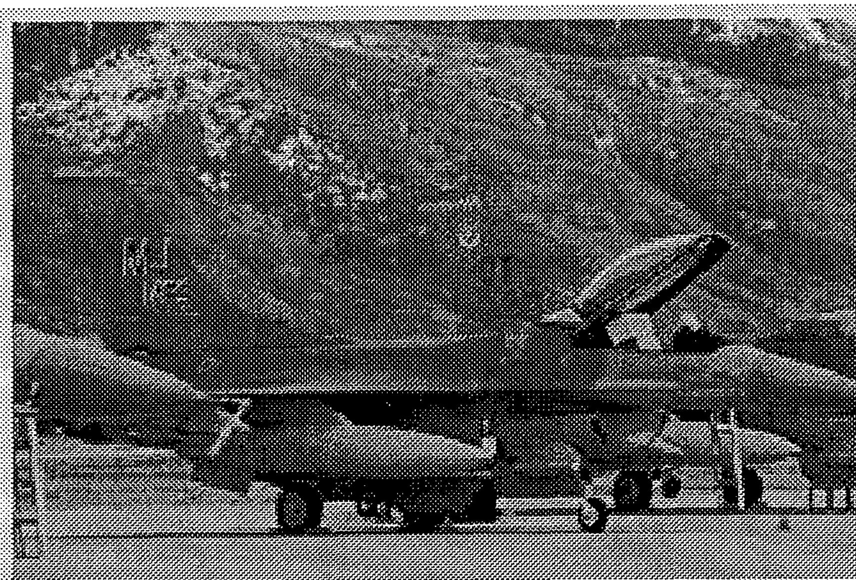
Evidence ... Commercial Practices
- *"24-Month" Production Aircraft*
- *$10M Savings on Current Contracts*
- *$10M Savings on Future Contracts*

- **AS 9000 Recognized - March 1998**
  - ✓ Basic 20 ISO 9001 Elements and an Additional 30 Requirements Unique to Aerospace Manufacturing
- **ISO 9001 Certified - 1996**
  - ✓ *1st Major Aircraft Manufacturer and Aerospace Company*
  - ✓ LMTAS Now Using ISO 9001 in lieu of Military Quality Standards
  - ✓ British Standards Institution (BSI) audits LMTAS continuously for ISO 9001
- **Commercial-Based Practices and Standards Are Applied for All Future Aircraft Programs and Projects**
- **Current Commercial Acquisitions:**
  Production F-16, KTX-2, F-2, JSF

... An Important Part of Our Commitment to be a Reliable, Affordable Supplier of Advanced Fighter Aircraft

Open Systems:
How We Are Doing Business

- Insulates Product from Parts Obsolescence
  - ✓ Hardware Independence
  - ✓ Software Portable
- Reduces Test and Integration Time Significantly *(Goal 1/3 Reduction)*
  - ✓ *Encapsulate the Software Change*
  - ✓ *Virtual Development Environment*
  - ✓ *Modular, Open System Interface Stds*
- Provides Capability Modularity
  - ✓ *Adaptable to Any Product Line*
  - ✓ *Easily Add/Delete for FMS Sales*
  - ✓ *Product Isolation for Secure Projects*
- Disciplines the SE Process
  - ✓ *Building Codes (Technical Architecture)*
  - ✓ *Open System Standards and Practices*



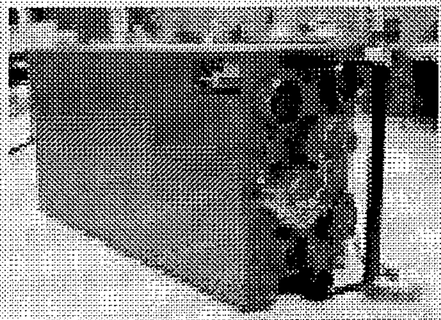
Evidence ... Commercial Standards
- *F-16 Block 60 Network (ATM)*
- *Commercial Core (F-16, KTX-2)*
- *Commercial Practices (ISO 9001)*
- *Paperless Contracting (Joint Management Council - Pilot Site)*

"Today's Environment Demands That We Closely Scrutinize the Way We Operate and Make Changes..."
Kathy Eppers, Director of Acquisition Reform Initiatives, LMTAS

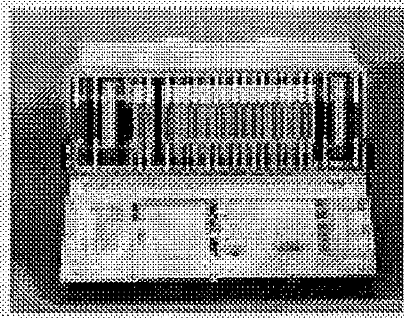
LOCKHEED MARTIN

Why Move to Commercial?

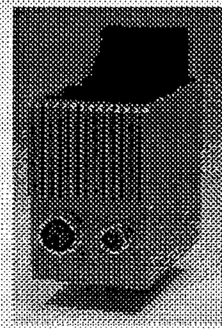
...To Lower the Cost of Military Avionics, the Military Must Shift from a Developer to a "Consumer" of Electronic Products...



Line Replaceable
Three-Level
Maintenance
1980s



Modular SEM E
Two-Level
Maintenance
1990s

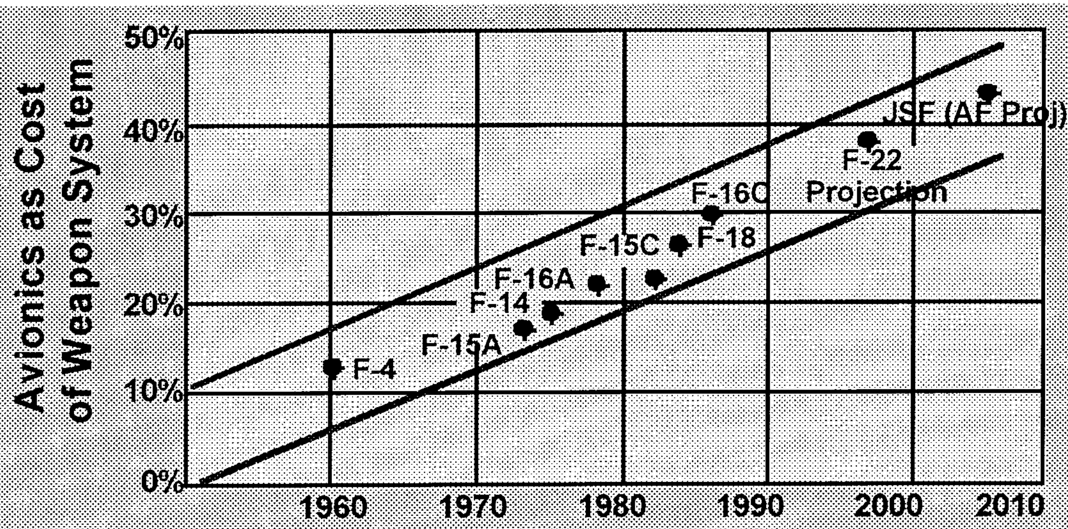


Modular COTS
One-Level
"Throw-Away"
Maintenance
2000s

- Military Driven by a Cost Paradigm
- Performance Parity – Equal or Better
- Military Support Strategy Must Evolve

Military Electronics Market Is Too Small To Drive Commercial Products

Commercial Practices are Needed for Military Systems to Reduce Costs

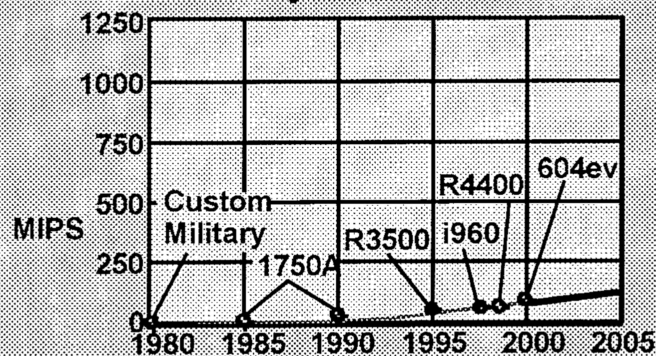


*Estimate Based on Total Production Plus Operational & Support

...Insert Up-To-Date Technology...

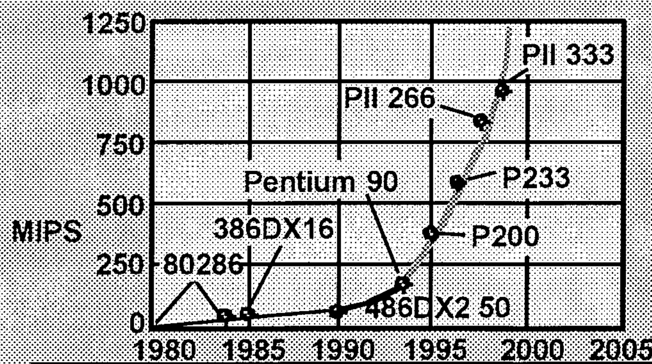
- Modular Avionics
- Integrated Sensors
- Open Systems
- "Throw-Away" Avionics
- Commercial Technologies

Military Aircraft CPUs



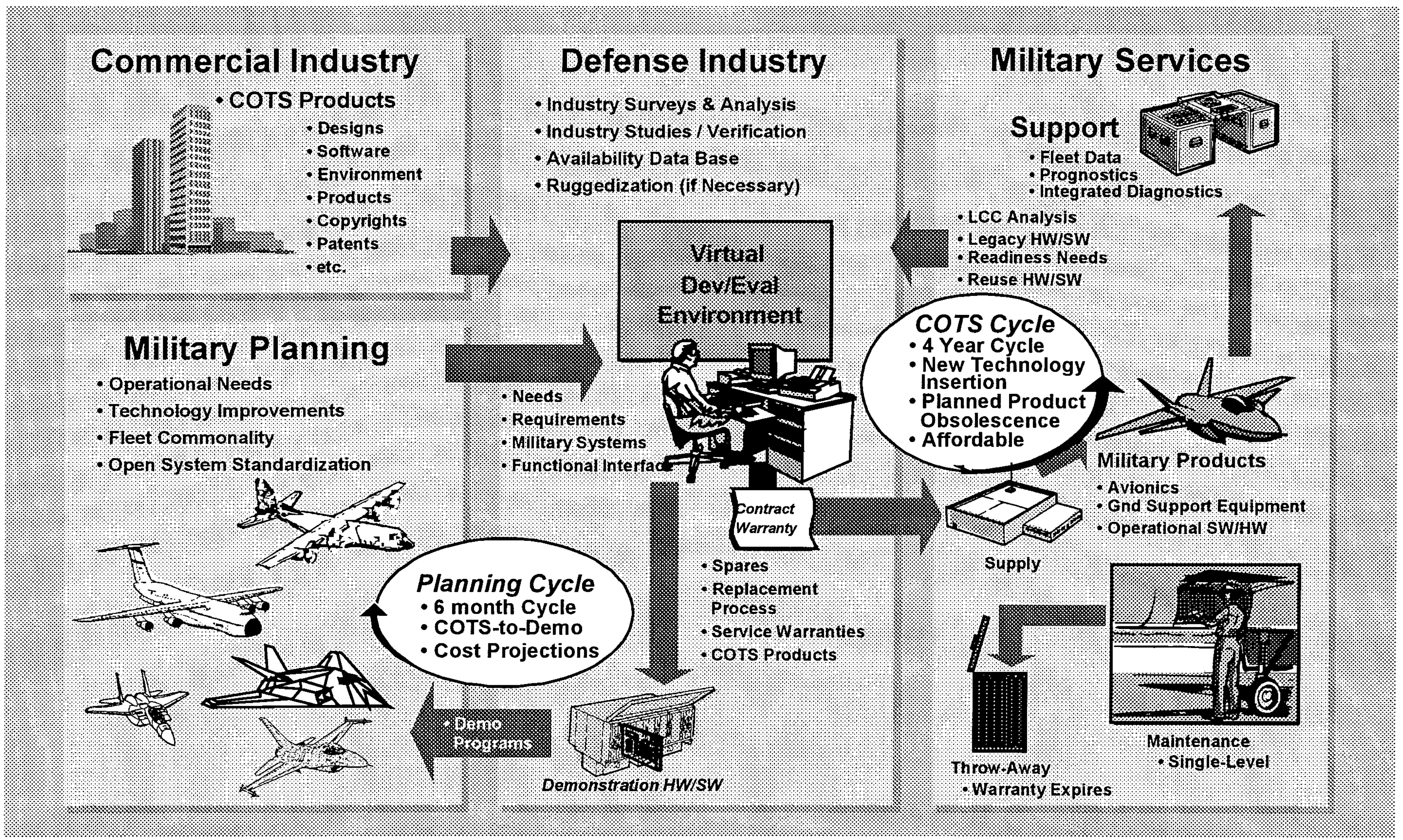
- 10-15 Years from CPU Choice to Aircraft IOC
- Software Not Compatible Between CPUs
- Design New Software Tools Per CPU
- CPU Ruggedized for Military

Commercial Intel CPUs



- 6 Month Interval Between New Products
- Existing Software Usable on New CPUs
- Software Tools Readily Available
- ISO9001 Qualification Requirement

Planning Is Essential



Measure & Monitor the Weapon System

What to Do ...

- **Prognostics**

  prediction of component degradation or impending failure

- **Autonomic Logistics**

  collect electronic information to determine, plan and perform needed maintenance with minimal downtime

The Payoff ...

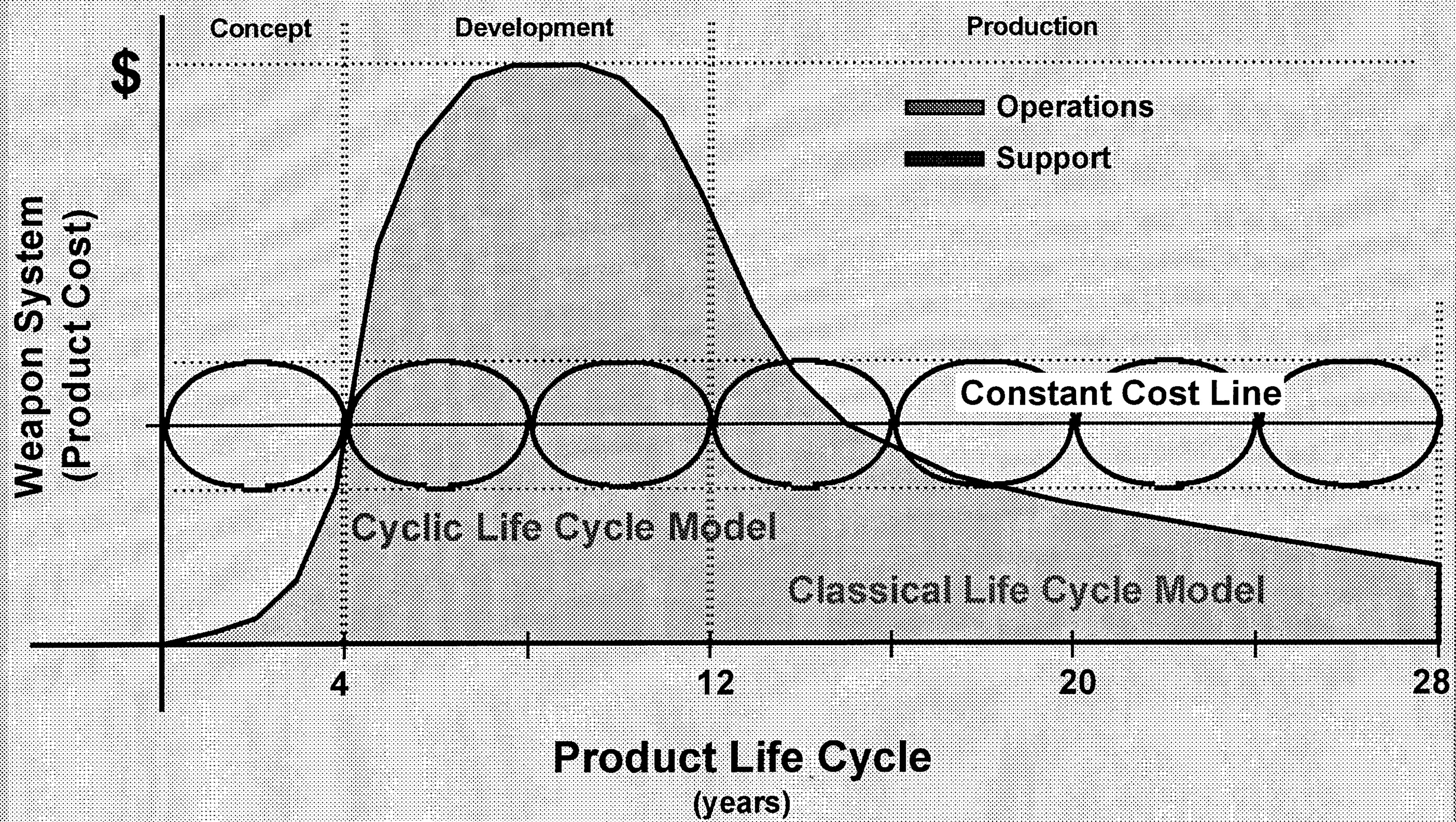
- **Significantly Lower Operations and Support Costs (20%)**
- **Enabler for Condition Based Maintenance**
- **Reduce the Costly Process of Inspections at Regularly Scheduled Intervals Which is Labor Intensive**

Evidence ...

- **Risk Reduction Program: Navy's Air Vehicle Prognostics and Health Management (AVPHM) Program**

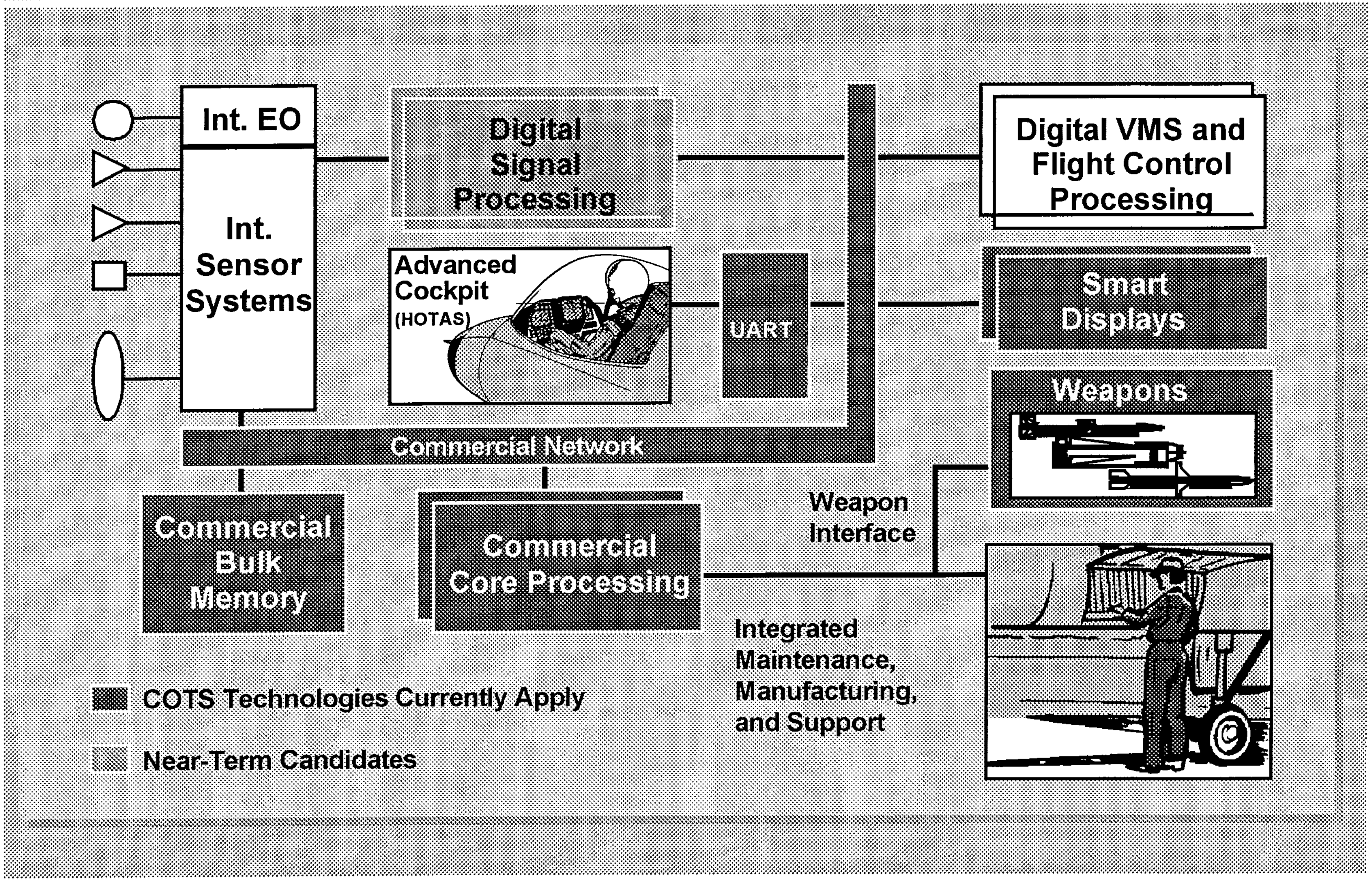
LOCKHEED MARTIN

Modeling for Lean Product Evolution



Evolve the Product ...

... Lower-Cost, Open System Architectures



Software Considerations in Highly Reliable Systems Development

Jasjit Heckathorn
Draper Laboratory

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DRAPER LABORATORY

Software Considerations in Highly Reliable Systems Development

- Software issues in Systems Development and Maintenance
- Software Systems Engineering
- Software Systems Engineering Practice at Draper

Software issues in Systems Development and Maintenance

- Systems are becoming larger, software intensive, and complex
  - Software is managing the increasing complexity of systems
  - Software provides the cohesiveness and control of data
  - Software provides the flexibility to work around/correct hardware or other problems that are found late in the development cycle
- Software cost is becoming the biggest driver of life cycle system cost since maintenance cost is mostly due to software changes required to
  - Respond to changing system requirements
  - Add functionality
  - Correct software or hardware problems
  - Upgrade obsolete hardware or COTS configuration
- Major systems failures are attributable to software failures
  - Ariane 5
  - Mars Pathfinder

Software Systems Engineering

- Application of appropriate software engineering technologies and processes to transform an operational need into a high quality and cost effective product
  - Technical considerations
  - Management considerations
- Technical considerations
  - System requirements and design
    - » Partitioning and allocation to software
    - » Hardware software trade-offs
  - Software requirements analysis
    - » Modeling
    - » Requirements specification and verification
  - Software design
    - » Use of design principles to facilitate maintainability and supportability
    - » Design documents

Software Systems Engineering

- Technical considerations (cont)
  - Code and unit test
  - Software integration and test
    - » Test Documentation
    - » Hardware simulations
    - » Software fault seeding
    - » Operational Scenarios
    - » Stress tests
  - Software/ hardware integration and test
    - » Interface tests
    - » Timing tests
    - » Hardware in the loop tests
  - System test

Software Systems Engineering

- Management Considerations
  - Requirements management
    - » Traceability
    - » Impact of change
  - Software planning
    - » Size, cost and schedule estimation
    - » Development approach (incremental, evolutionarily, spiral, prototype)
    - » Risk assessment
    - » Reuse, COTS considerations
    - » Products and Reviews
    - » Development environment
      - Methodologies and tools
    - » Test process and test environment

Software Systems Engineering

- Management Considerations(cont)
  - Software tracking and oversight
    - » Status reviews and design reviews
    - » Metrics
  - Software configuration management
    - » Baseline management
    - » Software build management
  - Software quality assurance
  - Communication and coordination

Software Systems Engineering Practice at Draper

- Draper provides innovative technical solutions associated with complex dynamic systems that must be highly reliable
  - Technical, reliability and safety considerations are and have always been of vital importance
- Recently management considerations have gained attention through the software process improvement initiative
  - Achieved SEI Maturity Level 3 in June 97
  - Standard process for the entire software development cycle exists and software engineering staff is trained
  - Projects use the Tailoring Guidelines to develop a software project plan, follow the plan and are monitored and audited against it
  - Projects Asset database contains methods, procedures, templates, tools, samples and Lessons Learned on projects
  - Metrics database is being populated for use in estimation
  - New technologies and tools are evaluated and inserted in projects

Software Systems Engineering Practice at Draper

- **Legacy Systems Development Experience**
  - A10 CDU version 1 1991- 1995
    - » Purpose - Integrate GPS into aircraft, and loosely couple with Inertial Nav System
      - New CDU hardware and software to couple the GPS and INS and control Improved Data Modem (IDM) communications
    - » Technologies
      - Object oriented design, Ada and assembly mix
        - Cadre Teamwork
        - Host VAX, Target Motorola 68020
        - XDAda (enhanced for for real-time tasking requirements)
        - In-circuit-emulator, Hardware-in-the-loop, Hot Bench
    - » DOD-STD-2167A process
      - Software Development Plan
      - Requirements management (home grown tool)
      - Configuration management (VaxCMS)
      - Tracking and Oversight (PS5, status meetings, software problem reports, user meetings, customer reviews)
      - Peer reviews
      - SQA and IV&V

Software Systems Engineering Practice at Draper

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❑ Legacy Systems Development Experience

- A10 CDU version 2   1996- 1998
  - » Purpose - Replace existing GPS and INS with Honeywell supplied Embedded GPS/INS (EGI)
  - » Technologies
    - Object oriented design, Ada and assembly mix
      - Host VAX, Target Motorola 68030
      - XDAda (enhanced for real-time tasking requirements)
      - In-circuit-emulation, Hardware-in-the-loop, CAST simulator and INS simulator, Hot Bench
      - COTS integration
  - » DOD-STD-2167A process enhanced with Standard Draper process
    - Software Development Plan
    - Requirements management (home grown tool)
    - Configuration management (Vax CMS, added scripts, automated build process)
    - Tracking and Oversight (MS Project, home grown metrics and problem tracking tool, user meetings, customer reviews)
    - SQA and IV&V
    - Peer reviews

Software Systems Engineering Practice at Draper

❑ Legacy Systems Development Experience

- GPS Ground Stations Replacement 1993-1995
  - » Purpose - Develop system design to replace obsolete computer hardware and software in GPS Ground Antenna and Monitor Stations
  - » Unique technical approach for analyzing requirements for legacy systems using existing documentation and discussions with users and maintainers of software
    - System requirements
      - Multiple views of the system (Behavioral, structural, data)
      - System Segment Specification (DOD-STD-2167A)
    - System Design
      - Reliability, maintainability, extensibility, supportability considerations
      - Open System Architecture, compliant with Industry standards
      - System Design Document (DOD-STD-2167A)
    - Software Requirements
      - Object Oriented Analysis (Rumbaugh)
      - Software Requirements Specification (DOD-STD-2167A)
  - » Process
    - Project plan
    - Methodology and tool assessment followed by team training
    - Requirements traceability (RTM)

Software Systems Engineering Practice at Draper

- New Systems Development Experience
  - Advanced Seal Delivery System (ASDS) 1994-1997
    - » Purpose - Provide guidance, navigation and control for manned submersibles and develop Integrated Control and Display (ICAD) processing
      - Graphical Users Interface (GUI)
      - Performance Monitoring Fault Localization (PMFL)
    - » Software Architecture and Top Level Design Reused from fielded Deep Submergence Rescue Vehicle (DSRV)
      - Host Sun, Target 68040 , C programming language
      - Reverse Engineer DSRV Software (Hindsight 20/20)
      - COTS Operating System (VxWorks)
      - Hardware in the loop
    - » Mil-STD-498 process enhanced with Standard Draper Process
      - Detailed software development plan
      - Requirements Management (home grown tool)
      - Configuration Management (Continus)
      - Tracking and Oversight (PS5, MS Project, home grown metrics and problem tracking tool, user meetings, customer reviews, unit test coverage, risk management)
      - SQA and IV&V
      - Peer reviews

Software Systems Engineering Practice at Draper

- **New Systems Development Experience**
  - **Simulation Based Test and Evaluation Capability(SiBaTEC)1995-1998**
    - » Purpose - Develop a user friendly real-time simulation facility that allows guidance systems developers to formulate and test performance and technology hypotheses
      - Graphical User Interface (GUI)
      - 3D animations
    - » State-of-the-art technologies, development environment and design tools
      - Object oriented analysis and design, C++
        - Multiple platforms (Solaris, IRIX, VxWorks, NT/95)
        - Rose, Purify, Quantify
    - » Standard Draper process facilitated by tools, with incremental development
      - Software development plan
      - Requirements Management (DOORS)
      - Configuration Management (Clearcase)
      - Tracking and oversight (MS Project and home grown metrics tool, collocated team, user meetings, regular status meetings with team and management, and customer/user reviews, risk list, process audits)
      - Peer reviews

Summary

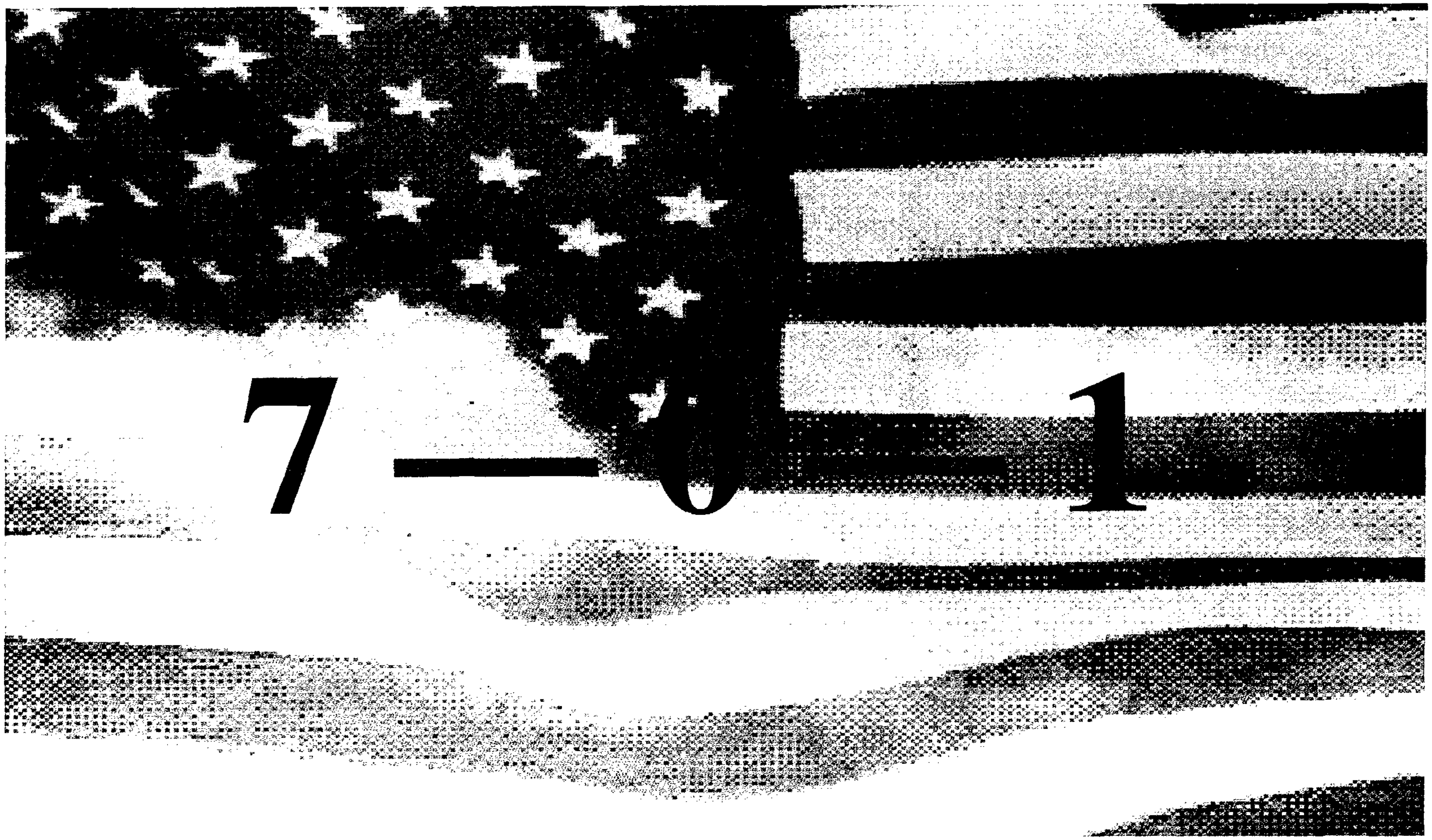
- Technical considerations and management considerations work hand in hand to produce a highly reliable, safe and cost effective system
- Use new technologies and tools, but assess risks and have a mitigation plan
  - » COTS can work both ways
- Design reviews, peer reviews are very helpful in early error detection
  - » Involve users, customers and other groups that have interfaces
- A process <u>appropriate</u> for the end use of the system can provide visibility, mitigate risk and enhance quality
  - » Planning, requirements management, configuration management, tracking and oversight, and risk management can help control cost
- Communication and coordination among the various developers can prevent a lot of interface problems and save time during system integration

Realizing the Revolution in Business Affairs

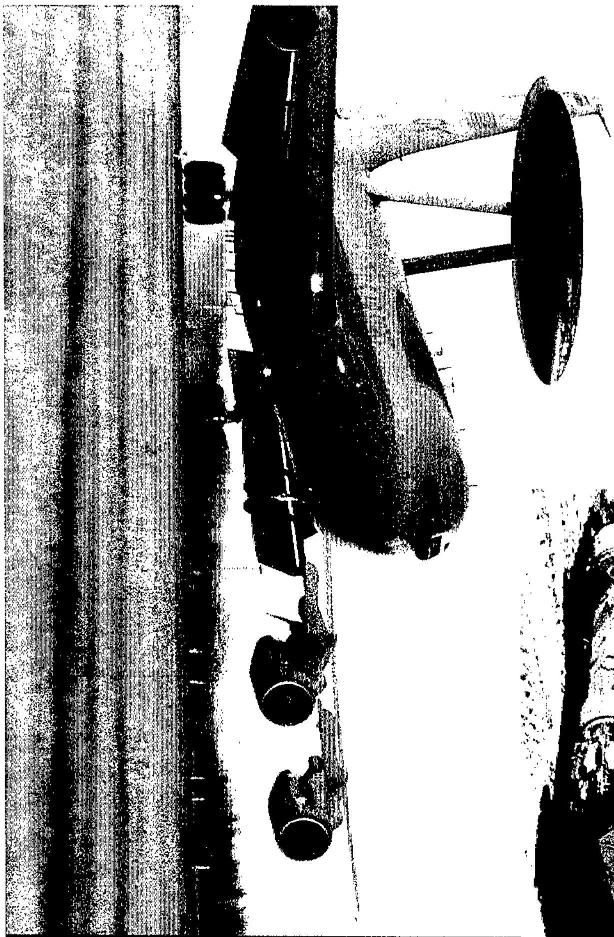
to Reinvent Logistics

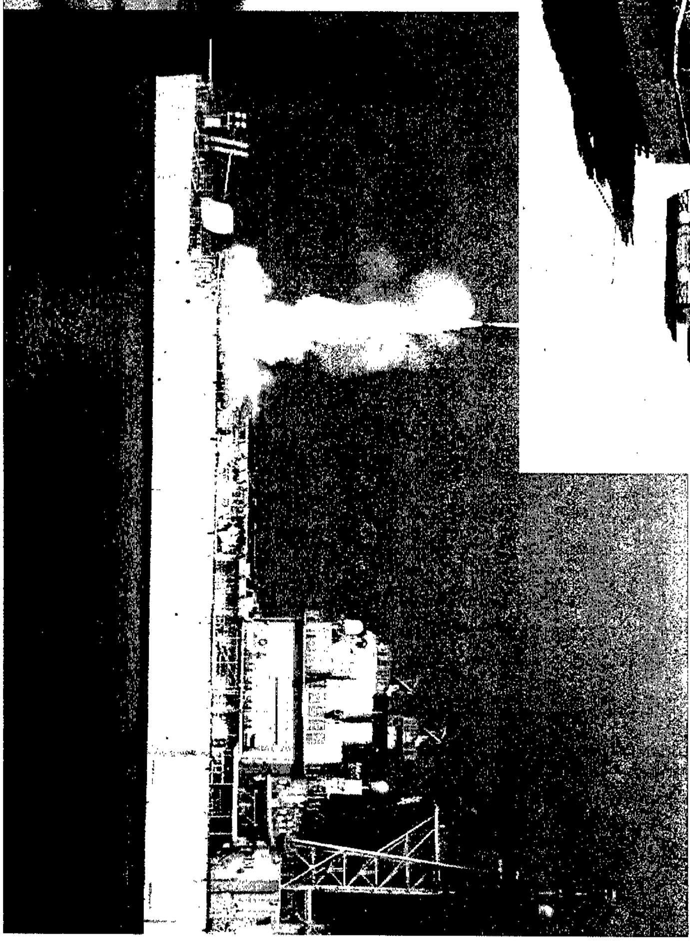
15 September 1998

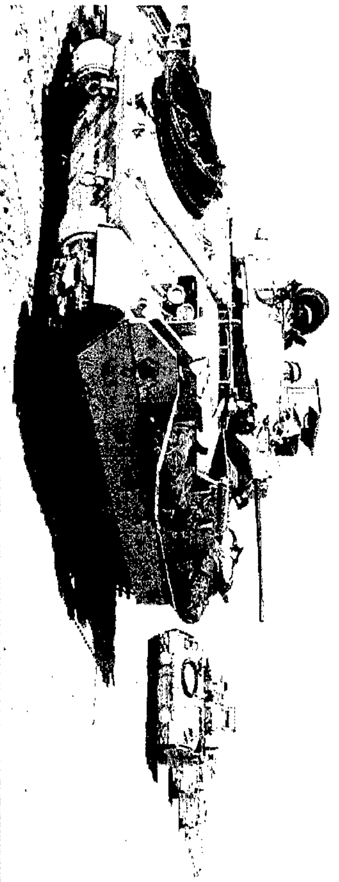
WE WON!



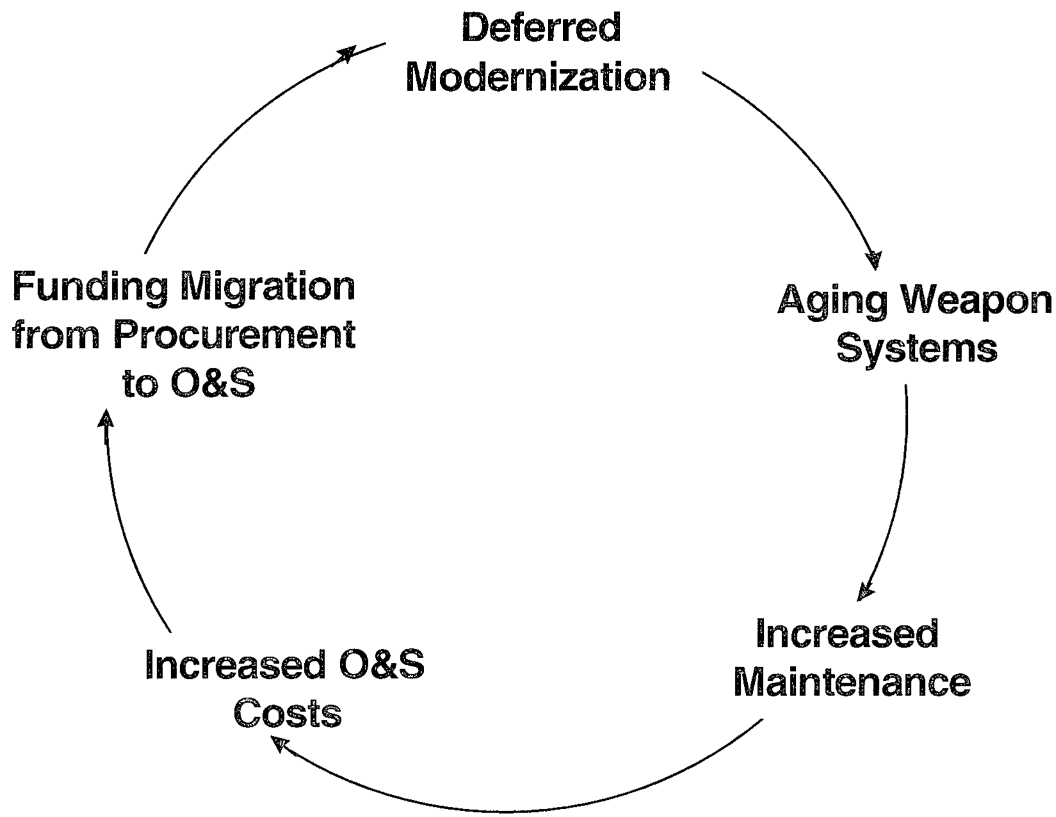
Battlefield dominance through acquisition and logistics excellence!





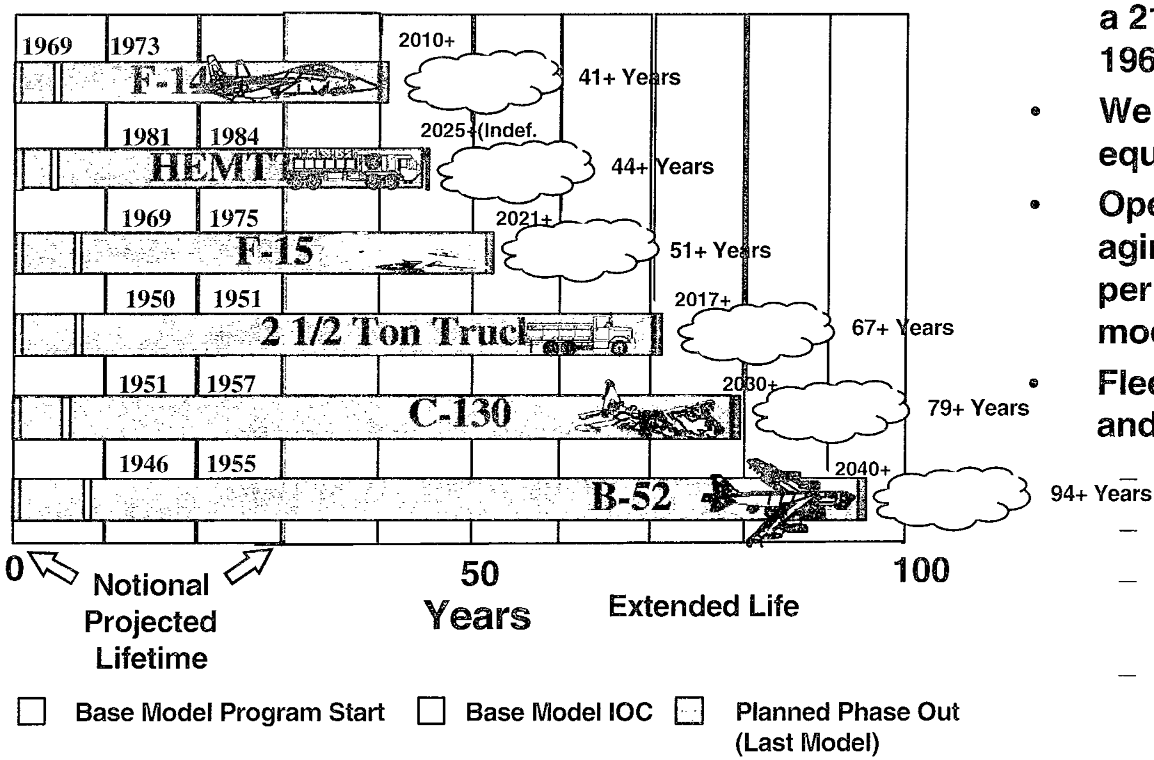


Our Challenge



To achieve required modernization, we must break the vicious cycle via process change and information technology!

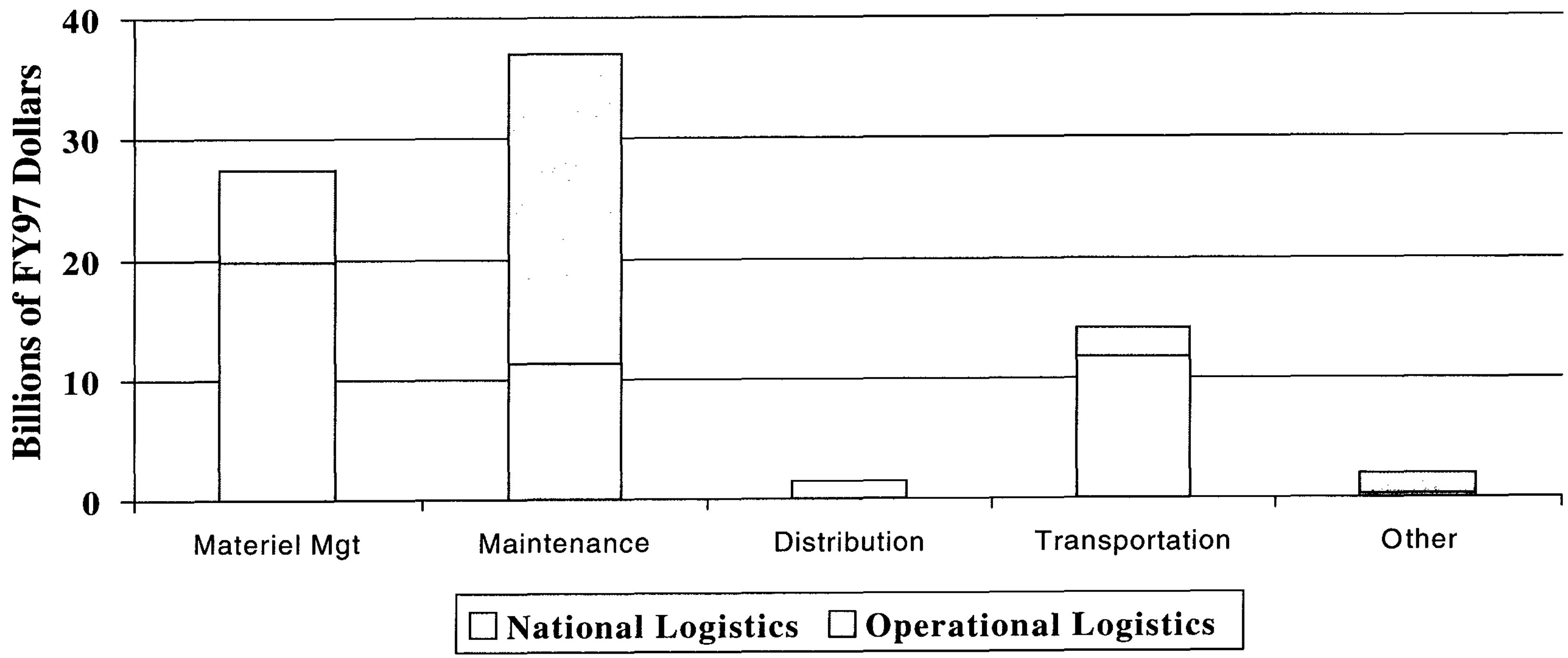
The National Challenge



- **We are asking our soldiers to perform a 21st Century mission with 1960's/1970's technology**
- **We are on our 3rd or 4th generation of equipment operators**
- **Operation and maintenance of this aging fleet consumes over $80 Billion per year - choking off resources for modernization**
- **Fleet is sustained by an infrastructure and processes that are also aged**
  - Systems software vintage 1960's
  - 37,000 personnel managing over 5 million national stock numbers
  - 375,000 personnel providing National-level logistics support
  - Multi-million dollar equipment grounded due to lack of 1960's vintage parts

Meeting this challenge will require sustained senior leadership from the Executive Branch, Congress, and industry!

Functional Costs



Where are we spending money versus where are we spending energy?

Increased Frequency of Deployments

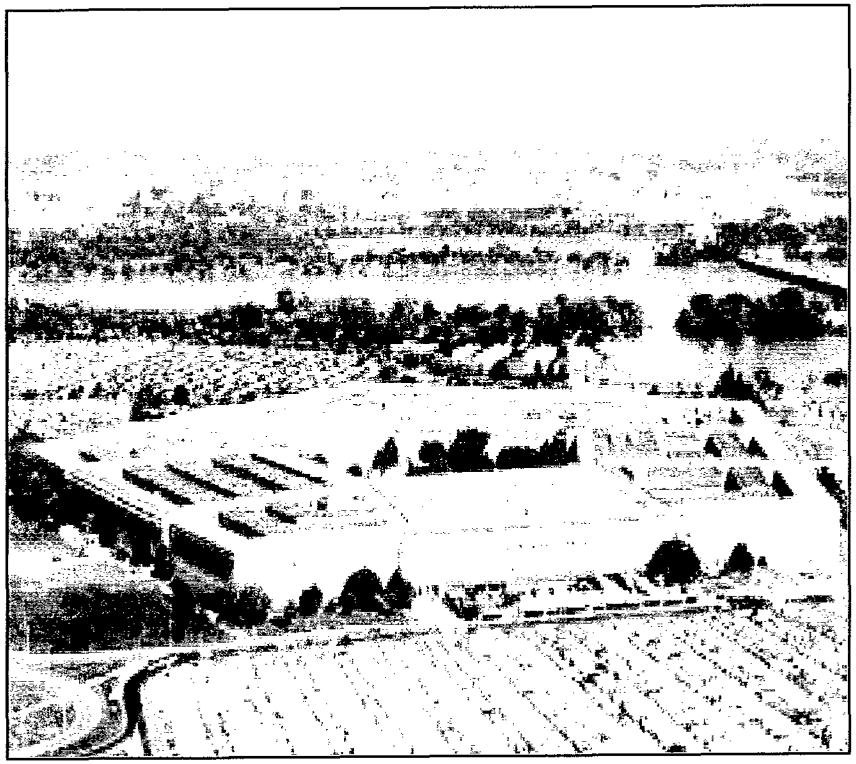
National Challenge

- Fully integrated weapon system life cycle process
- Providing effective and efficient support to the warfighter
- Guided by metrics, accountability and incentives
- Integrated through near real-time digital information exchange
- Across a global community
- Maximizing commercial sector capabilities
-
-

Key Areas

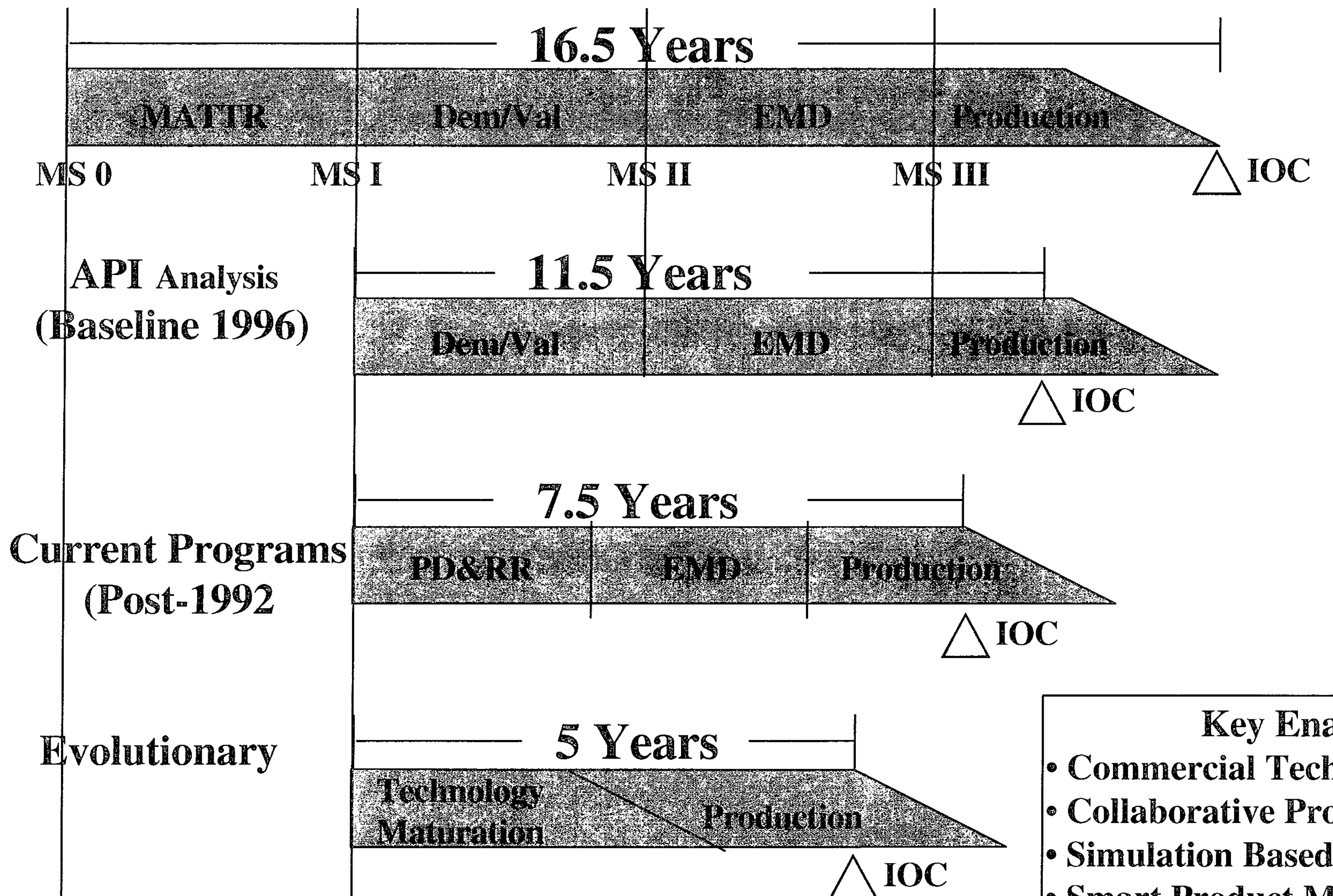
- Continue acquisition reform
- Deploy electronic contracting
- Reinvent logistics processes

Acquisition Reform



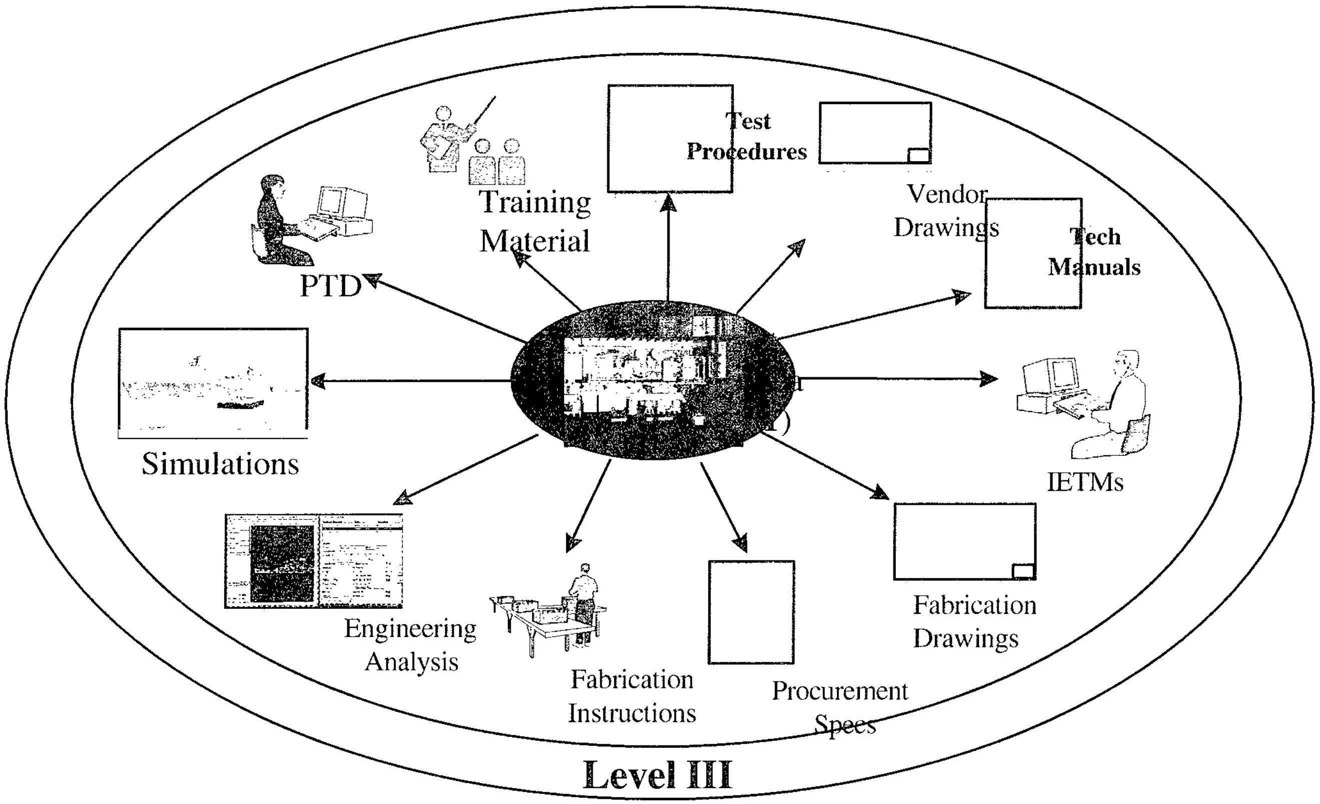
Working together to rapidly field needed capability

Reducing Time To Market



Key Enablers
- Commercial Technologies
- Collaborative Processes
- Simulation Based Acquisition
- Smart Product Models

Simulation Based Design: Reducing O&M Costs



LPD-17
Cost Avoidance

- **$1 Billion in Procurement**
- **$4 Billion in O&M**
- **$10 Billion in Personnel**

Smart product models being applied to reduce material and personnel requirements

Smart Product Models

Family Medium Tactical Vehicles (FMTV)

Reduce O & S Costs

Objectives:
Achieve a DoD-wide common technical and process framework where product model, support, and management data are shared among life cycle stakeholders

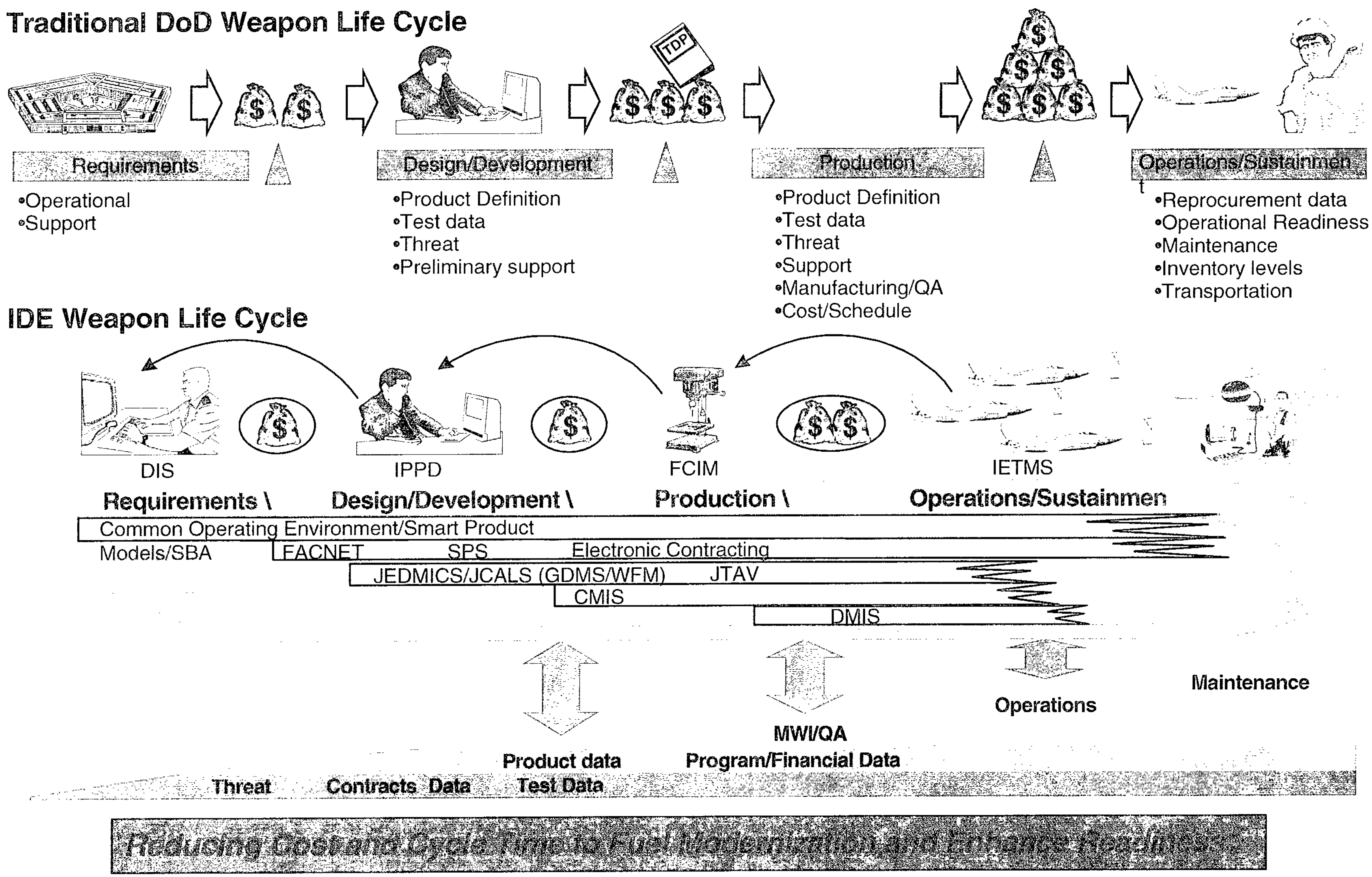
KC-135 Upgrade

Reduced Cost per In-flight Refueling

C^3I-Integrated Communications

Cost, Schedule, and Performance

Life Cycle Vision



Creating a Life Cycle Economy

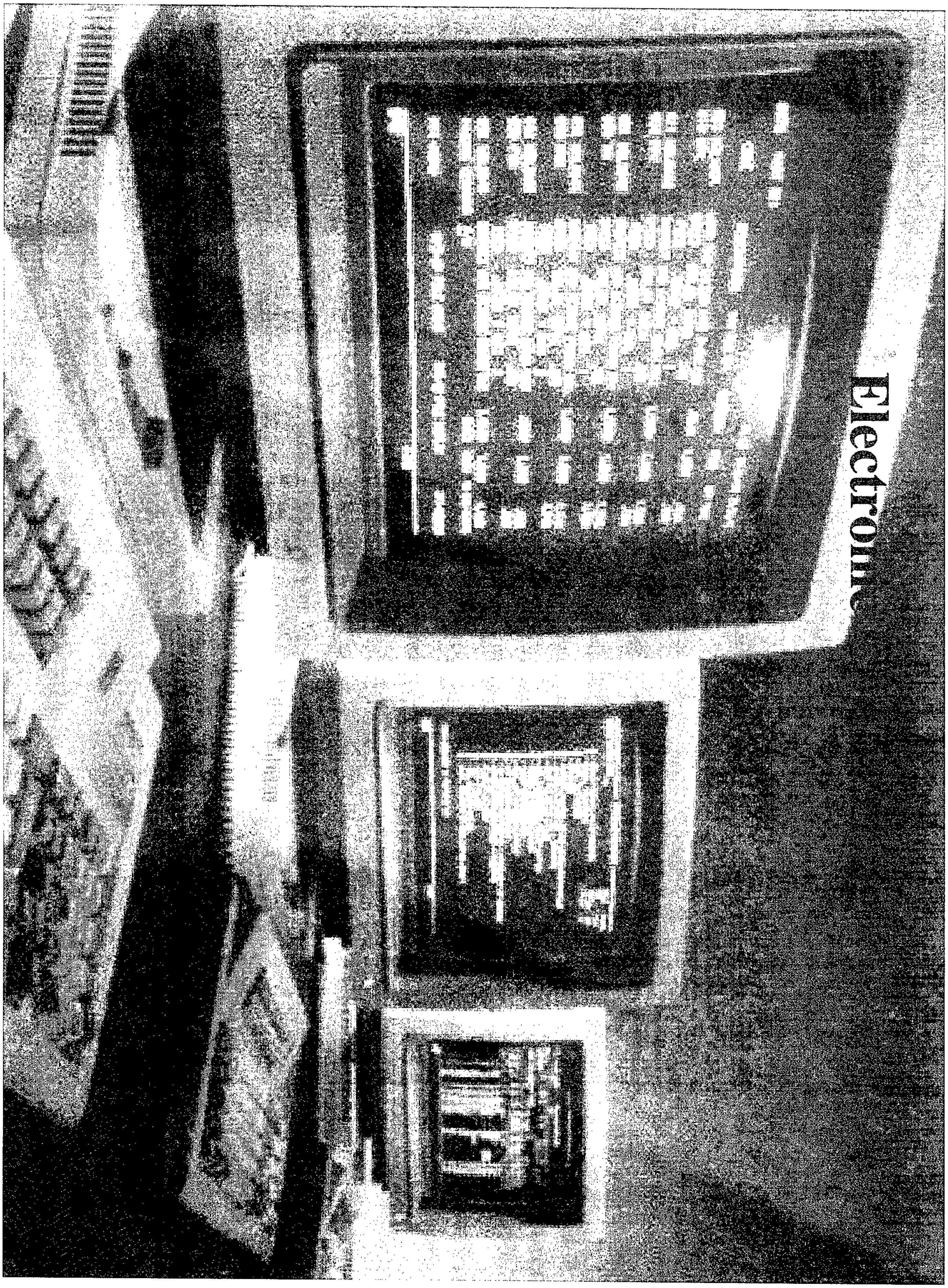
- Implement total ownership cost pilot programs

Define traditional logistics cost baseline (draft)

Implement Logistics Technology Insertion Process

Define links between budget, appropriations, cost, and readiness (FY99)

-



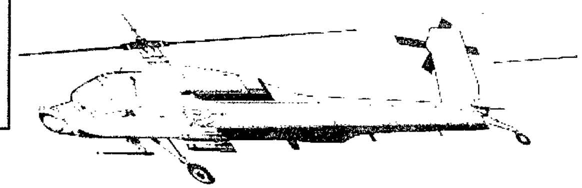
Objectives of Logistics Reinvention

- ★ Improve service to the warfighter
- ★ Reduce costs to enable modernization
- ★ Eliminate infrastructure while dramatically improving response time
- ★ Reduce logistics footprint to enable agility

Developing the Business Vision

1998 Logistics Strategic Plan — Joint Vision 2010 — GCSS — National Performance Review/ Defense Reform Initiative

- Integrate Objectives
- Describe Logistics Context
- Determine Appropriate Economic Model
- Identify Business Opportunities

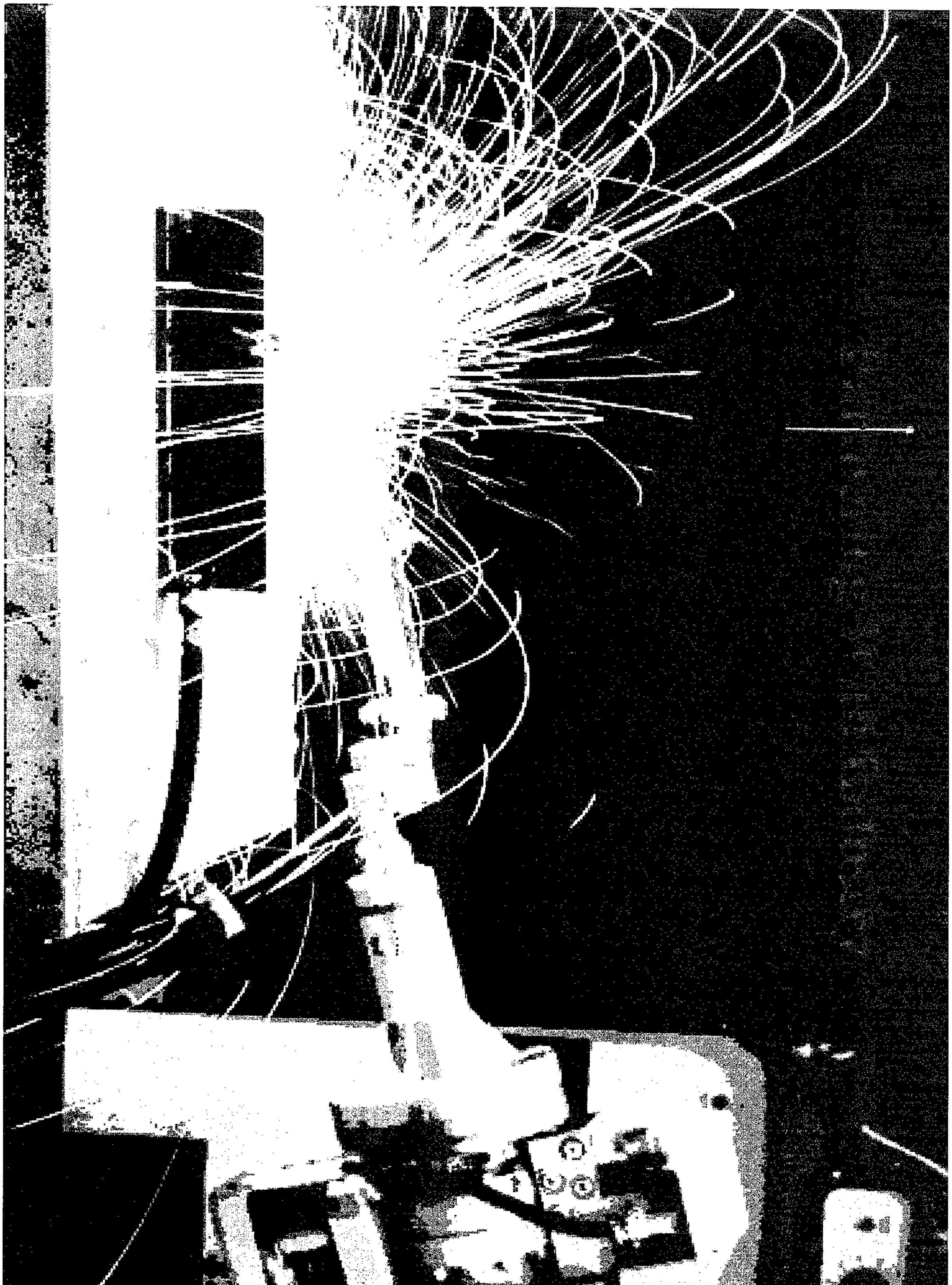


- Operational Business Vision
- Operating Principles
- Functional Requirements
- Business Rules

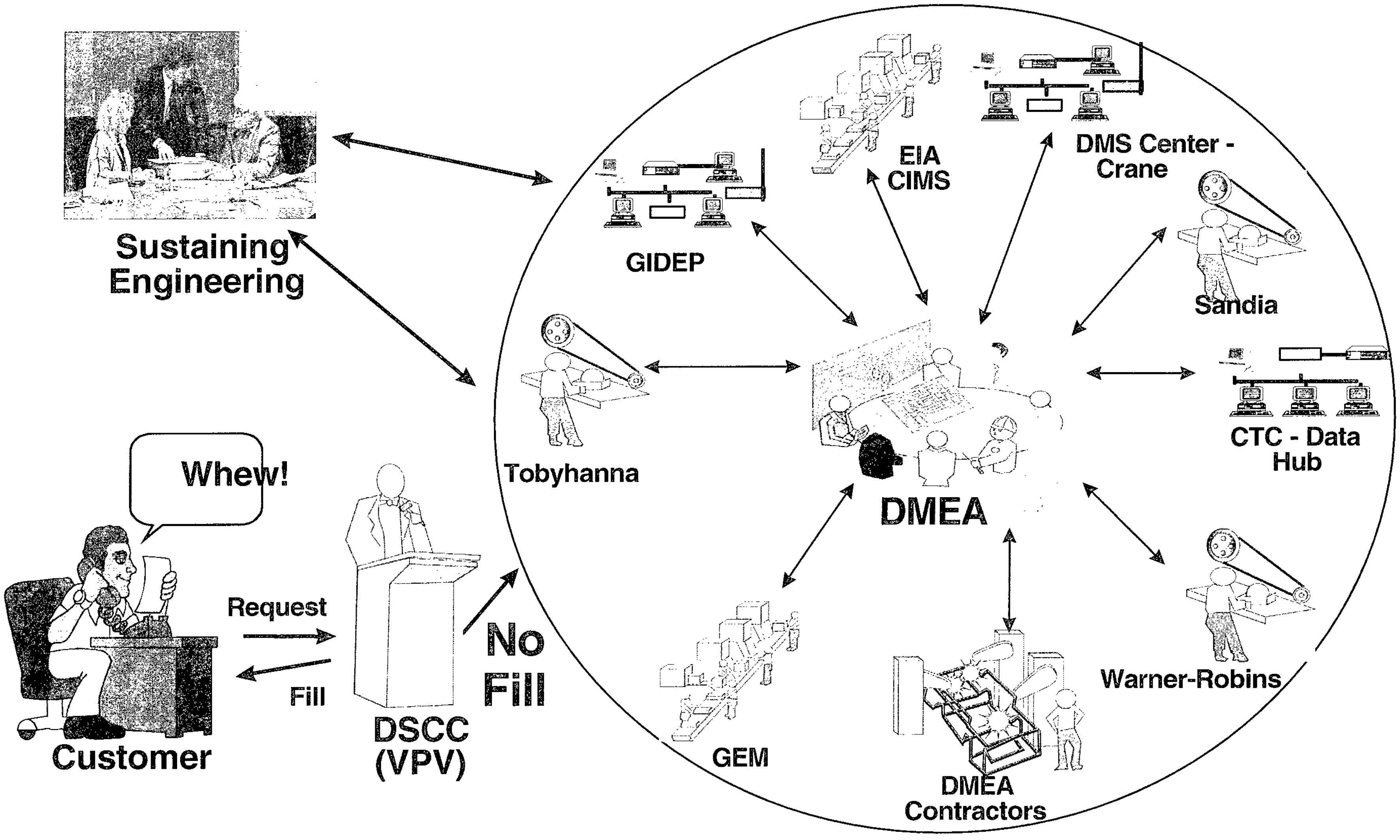
To reduce total ownership costs, we must focus on the warfighters' requirements!

Reinventing Logistics

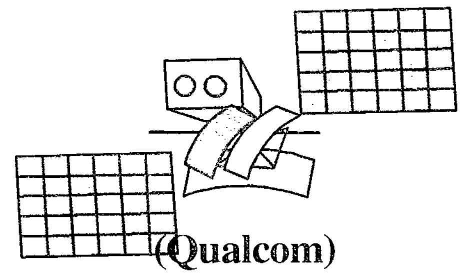
- Partnering with industry
- Reinvention of logistics processes based on world-class benchmarks
- Deployment of interoperable logistics information systems
- Rightsizing the infrastructure

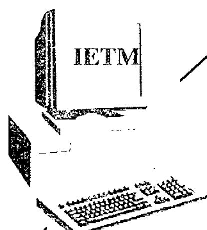


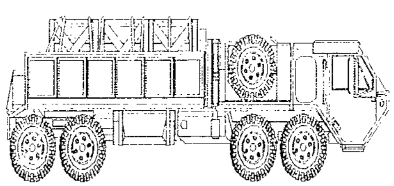
Virtual Parts Supplier Base



Integrating Supply and Maintenance to Achieve Predictive Readiness





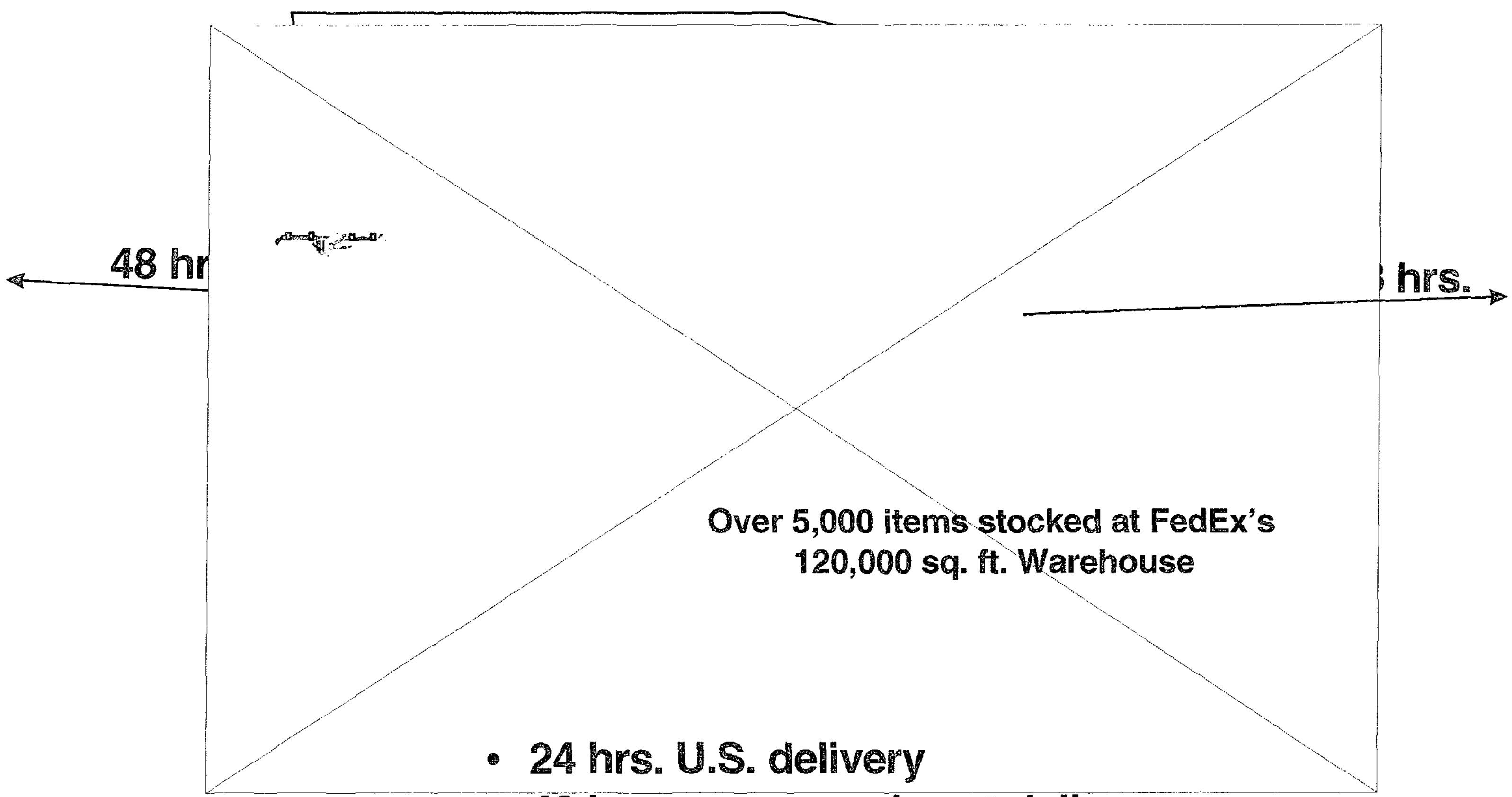


- Total fleet status
- Statistical demand
- Condition reporting
- Anticipated failures
- Tailored war reserve packages

TACOM

Enhancing agility by optimizing deployment packages through predictive readiness

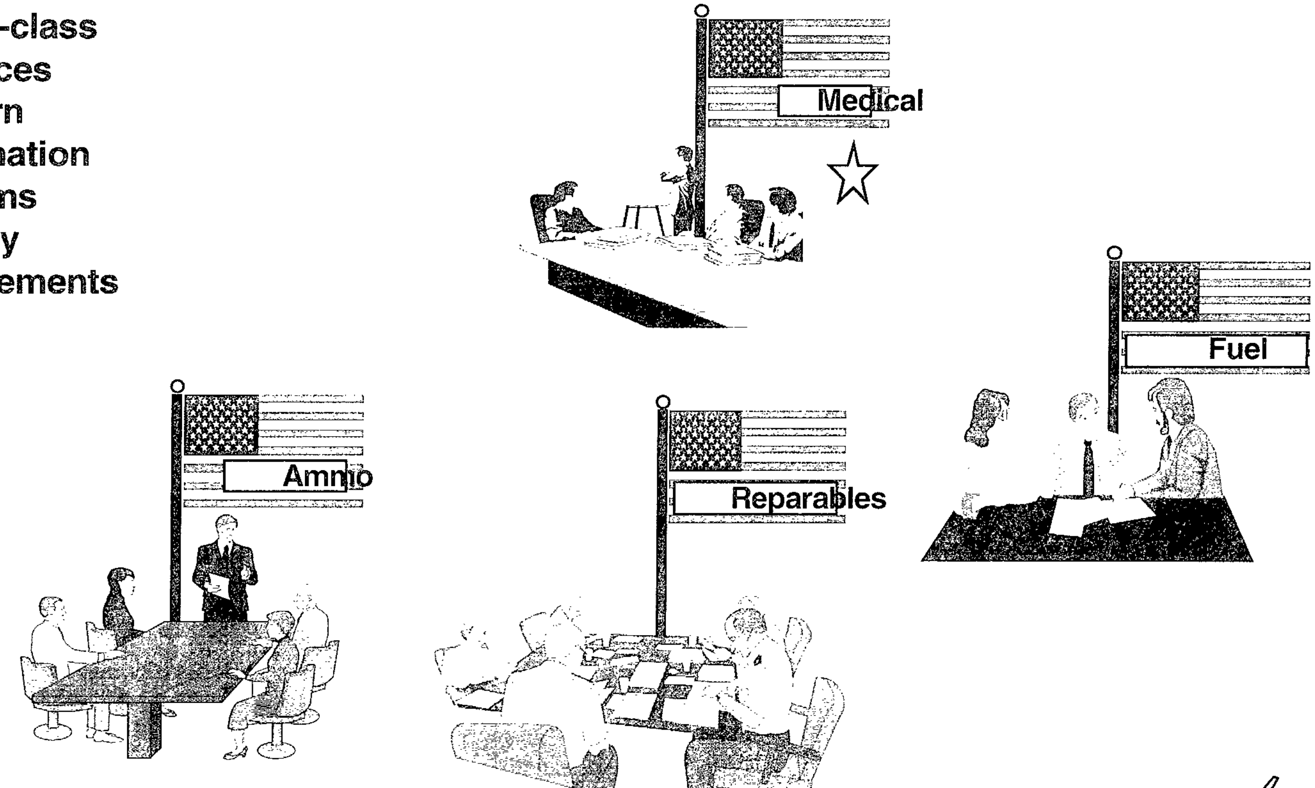
Partnering with Industry: FedEx Premium Service



- 24 hrs. U.S. delivery
- 48 hrs. overseas airport delivery
- 99.9 percent inventory accuracy
- 98.0 percent on time delivery
- Total Asset Visibility

The 90-Day Campaign

- World-class practices
- Modern information systems
- Military requirements

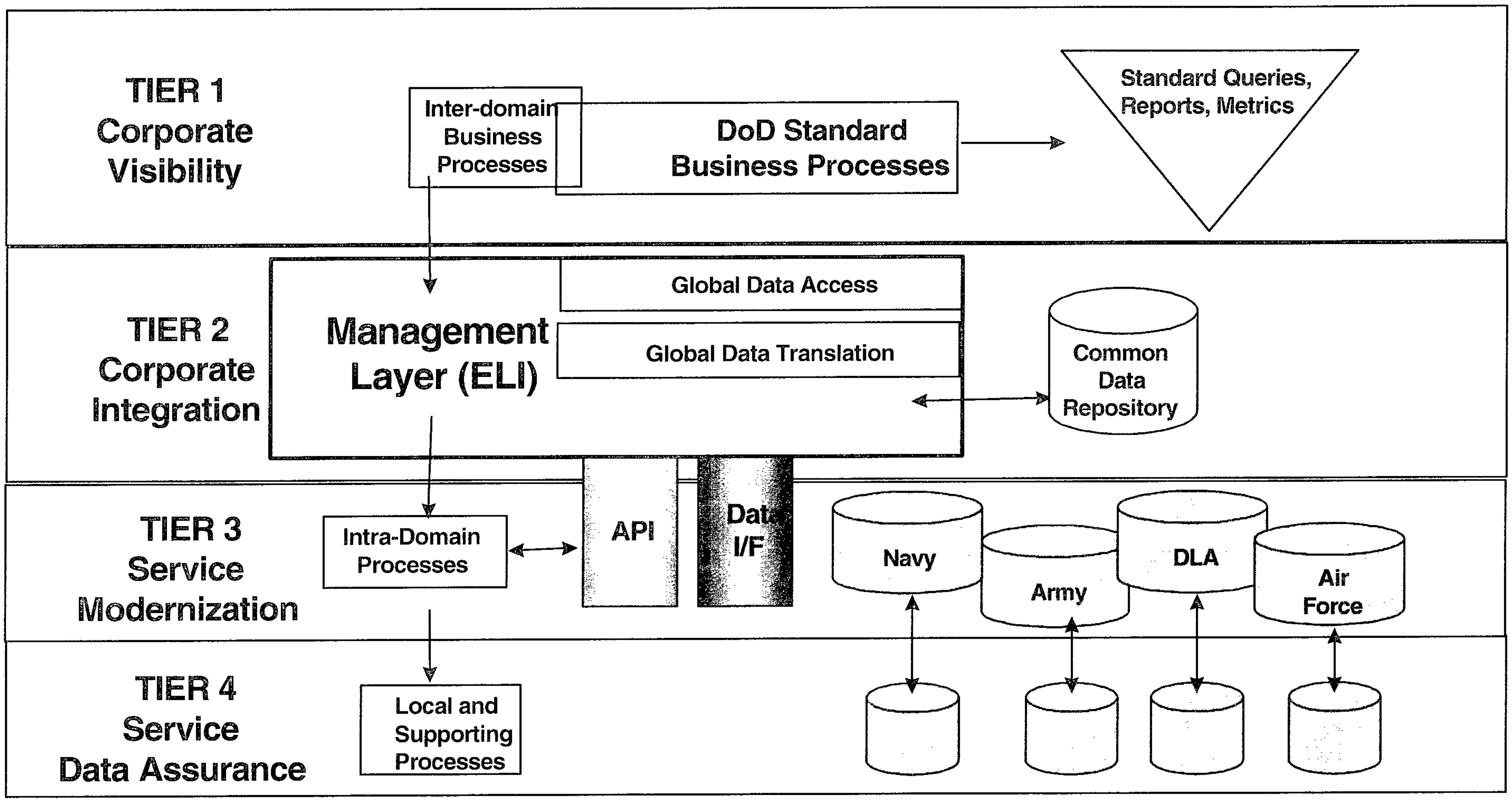


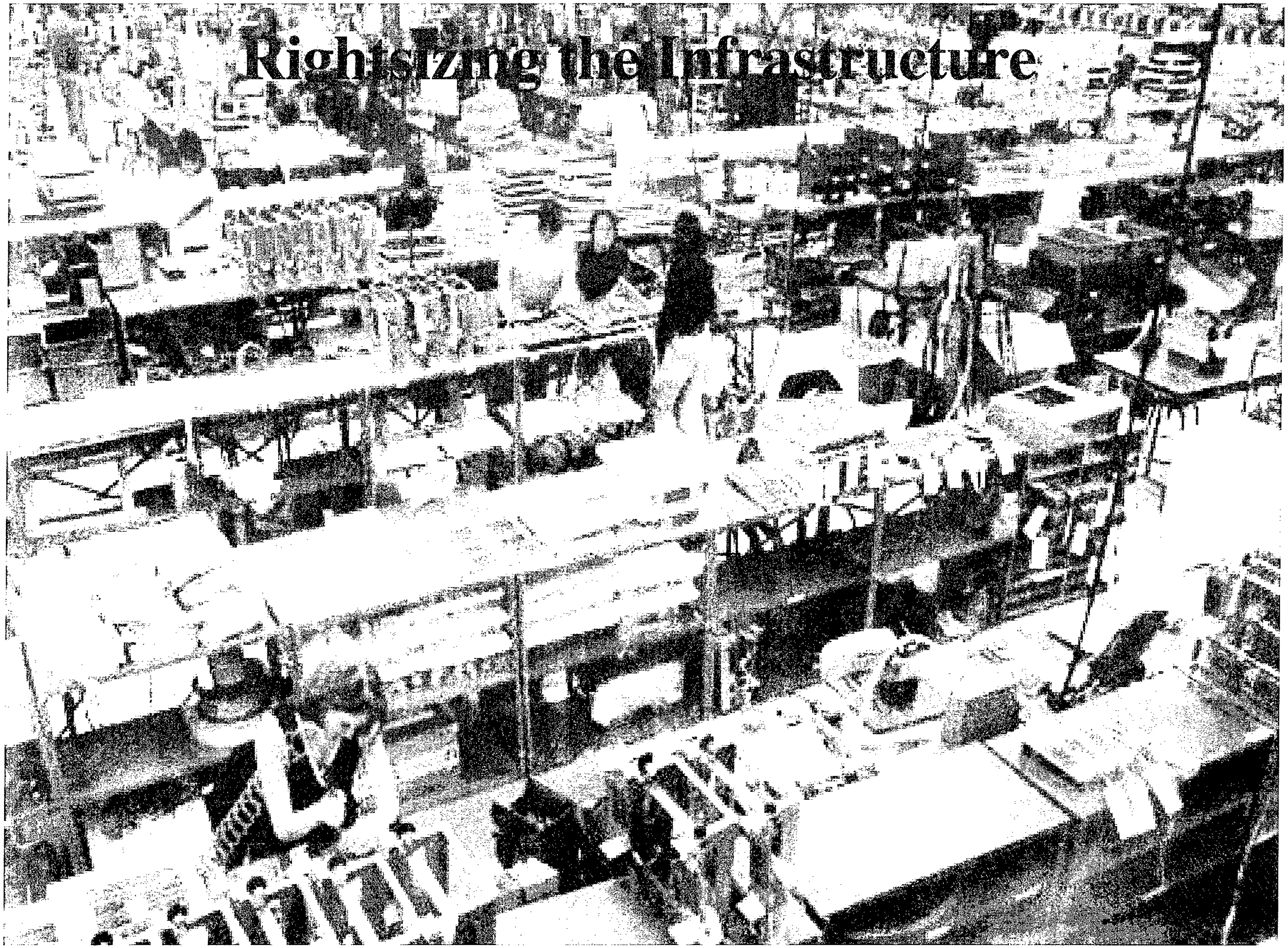
Customer-focused tiger teams to enable integrated supply chain management

We Need a Broad Spectrum of Help

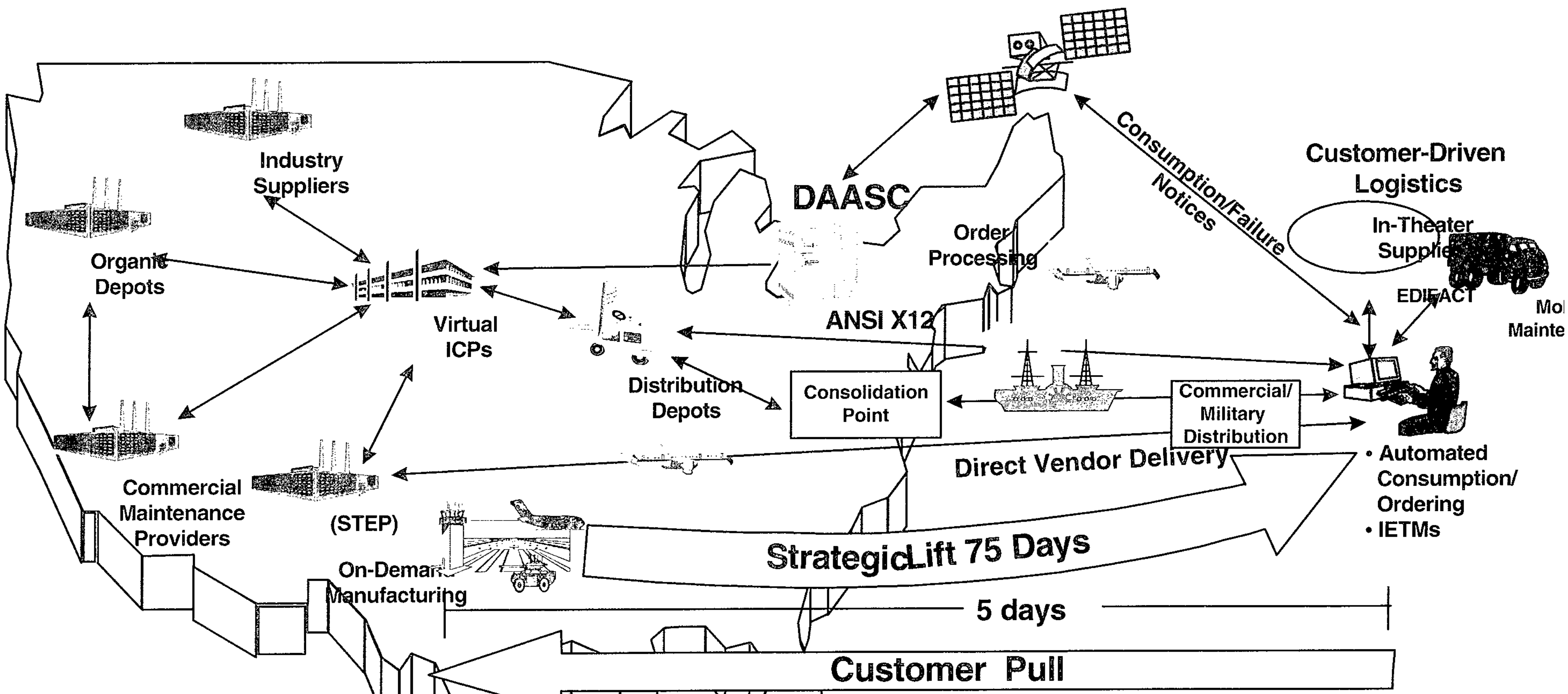
- Industry best practices by commodity class/ market segment
- DoD unique military requirements
- Information system implementation
- Transition planning and implementation

Near-Term Architecture




Rightsizing the Infrastructure

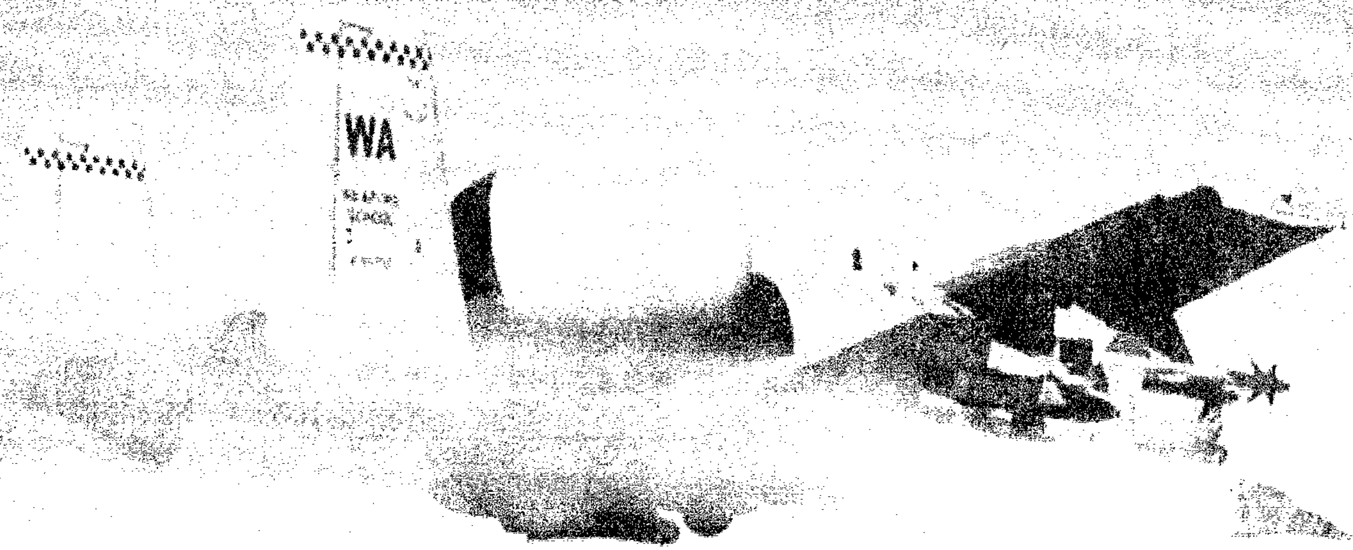
Future Logistics Environment



Asset visibility and logistic C² enabling customer-driven logistics processes focused on superior service to the Warfighter:
- Rapid strategic lift
- 5-day response time
- Confidence in re-supply
- 2-month depot repair time

*With appropriate surge capability

Supporting the Warfighter



The Paradigm Shift

Traditional Approach

Define Unique Interfaces

Develop Components

Integrate Components

Use & Support the System

Open Systems Approach

[redacted] interfaces

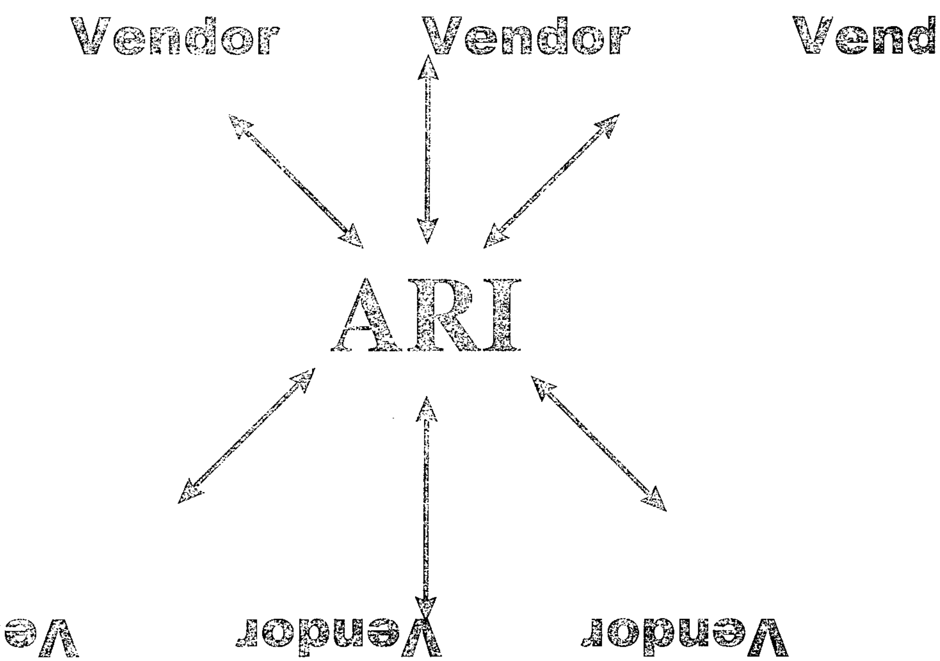
[redacted]

Integrate components

Use and support the system

ARI Focus

- Establish Vendor Awareness
- Encourage the Development of Open System Products



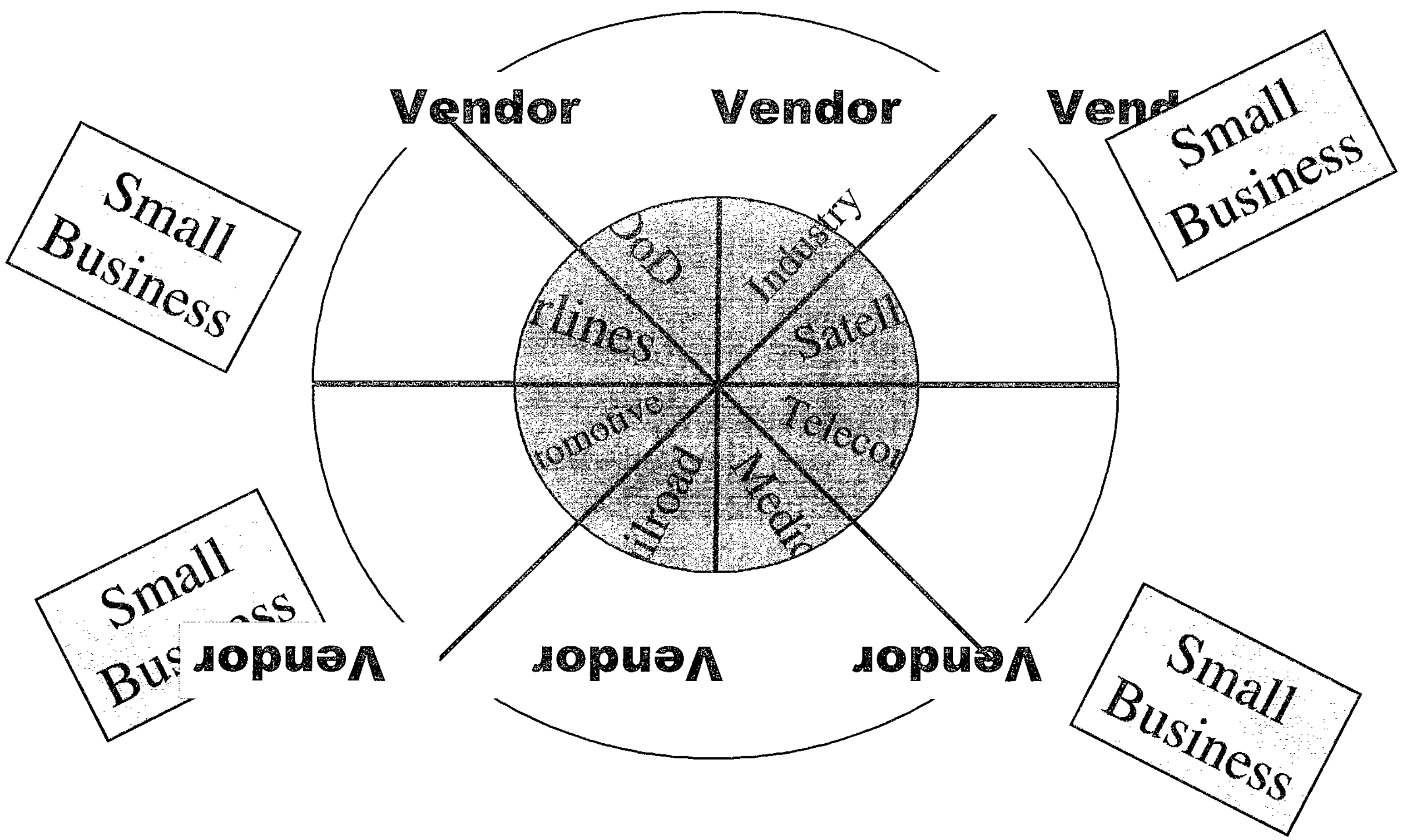
ARI Status

- Will become a program in the EAO instead of an IPT, focused upon:
  - DoD related Test and Diagnostic R&D issues
  - Common Test and Diagnostic issues within the TDC

Paradigm Shift

As a member of the consortium, the DoD will be positioned along side other industry test customers

Test and Diagnostics Consortium



Vision

Our Vision is to work together to optimize the test and diagnostics environment through communication of business, technological and customer-oriented issues and concerns.

Mission

1. We are dedicated to working together to identify and address the mutual test and diagnostics issues and concerns.

Mission

2. We will foster the development of more effective test and diagnostics tools, systems and processes.

Mission

3. We will facilitate communication in the test and diagnostic community

Scope

- Test
- Diagnostics
- Information Flow / Exchange
- Processes

Scope

- Test
- Diagnostics
- Information Flow / Exchange
- Processes

Benefits

- Strategic Partnerships
- Improved Test & Diagnostic Capabilities
- Access to Test & Diagnostic Information

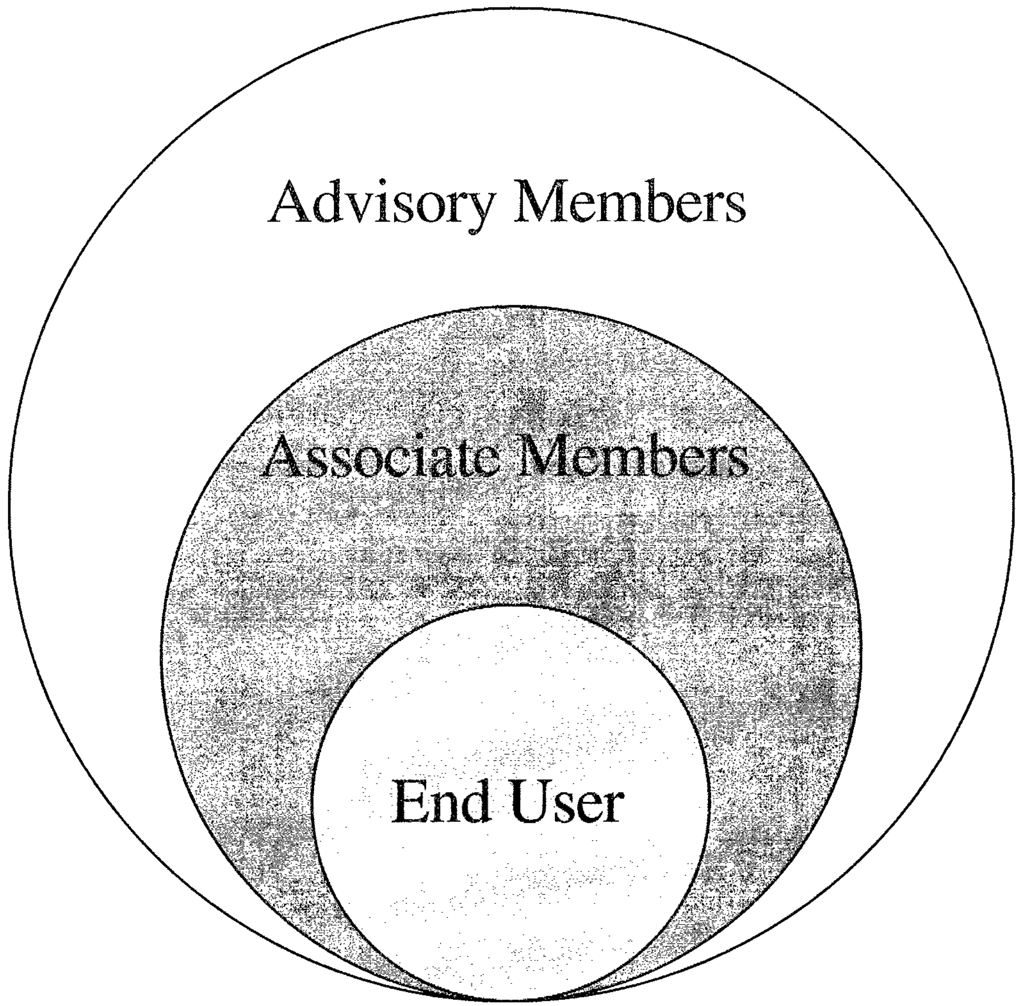
Benefits (continued)

- Open Forum
- Unified Voice
- Communication Opportunities
- Leverage (costs, information, R&D)

Benefits (continued)

- Identified Issues & Initiatives
- Funding
- Advisory Role

Membership



Schedule of Events

January 1, 99
Publication of Charter
and Membership Rules

June 99
Open Membership Meeting

JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG

March 4, 99
Membership Meeting
Orlando, FL

Systems Engineering & Supportability
Conference & Workshop

Model Based Test Generation for Software Systems

Brian Miller
Teradyne Software & Systems Test
www.teradyne.com/sst

brian.miller@teradyne.com

TERADYNE Software & Systems Test

TestMaster is Deployed in a Wide Range of Telecom Companies:

Lucent	Ericsson
Nortel	AT&T
Motorola	Bellcore (SAIC)

... and these Mil/Aero Organizations:

F16 Fire Control Computer:
- SAIC - Advanced Integration & Test Facility
- Wright Labs

F15 Radar - PIVT Program:
- Raytheon (Hughes Radar) & Warner-Robins

Jet Propulsion Labs - Image Processing

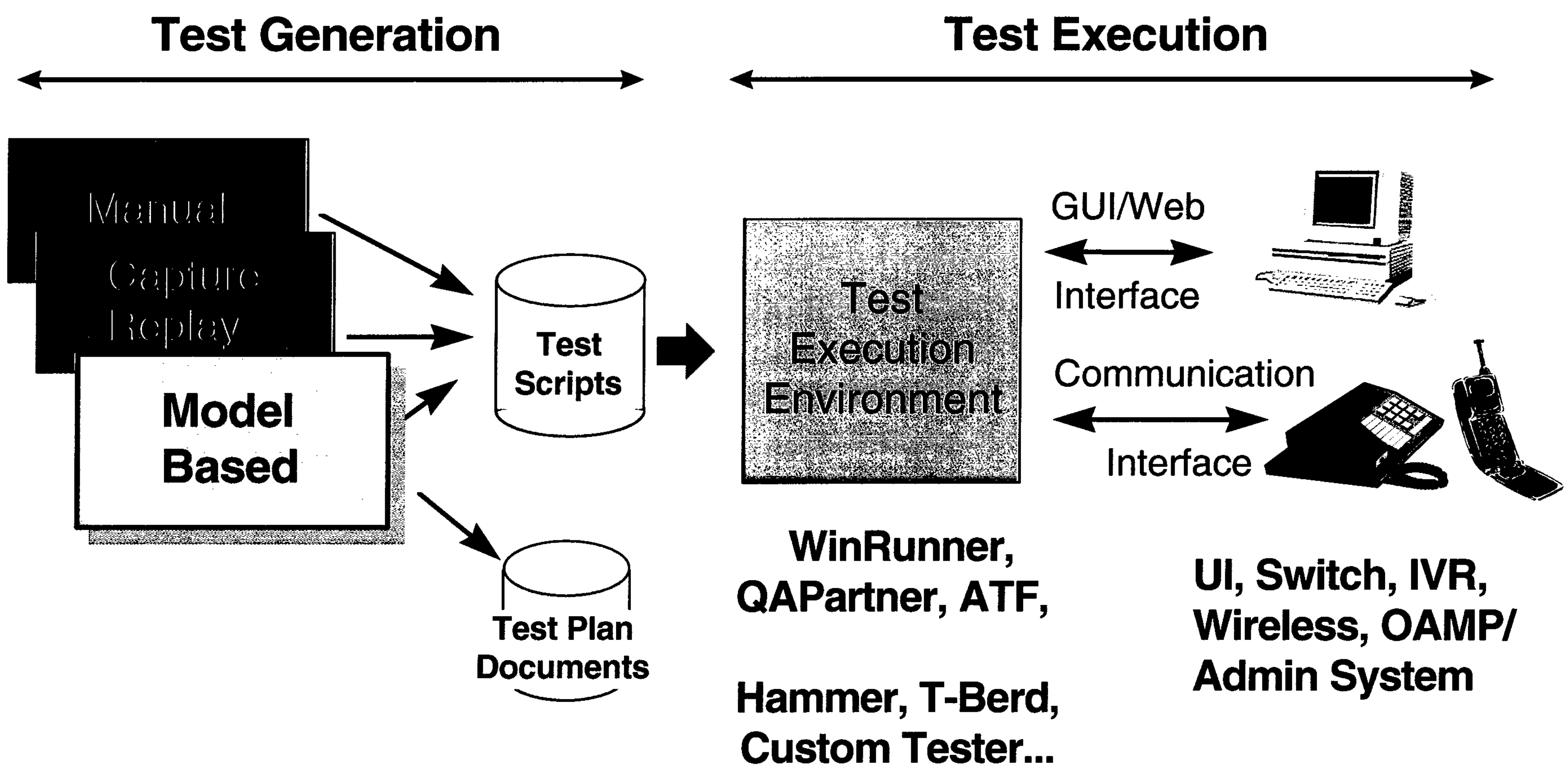
TERADYNE Software & Systems Test

The Telecom Industry Characteristics that Drove TestMaster's Acceptance include:

- Need for high quality/reliability systems
- Process-focused software development methodology
- Fast response to change in specifications

TERADYNE
Software & Systems Test

Testing has Two Phases: Generation and Execution



TERADYNE
Software & Systems Test

A Behavioral Model Defines the Use of a System at One or More of its Interfaces

Start with typical use cases, focus on the primary interfaces of system

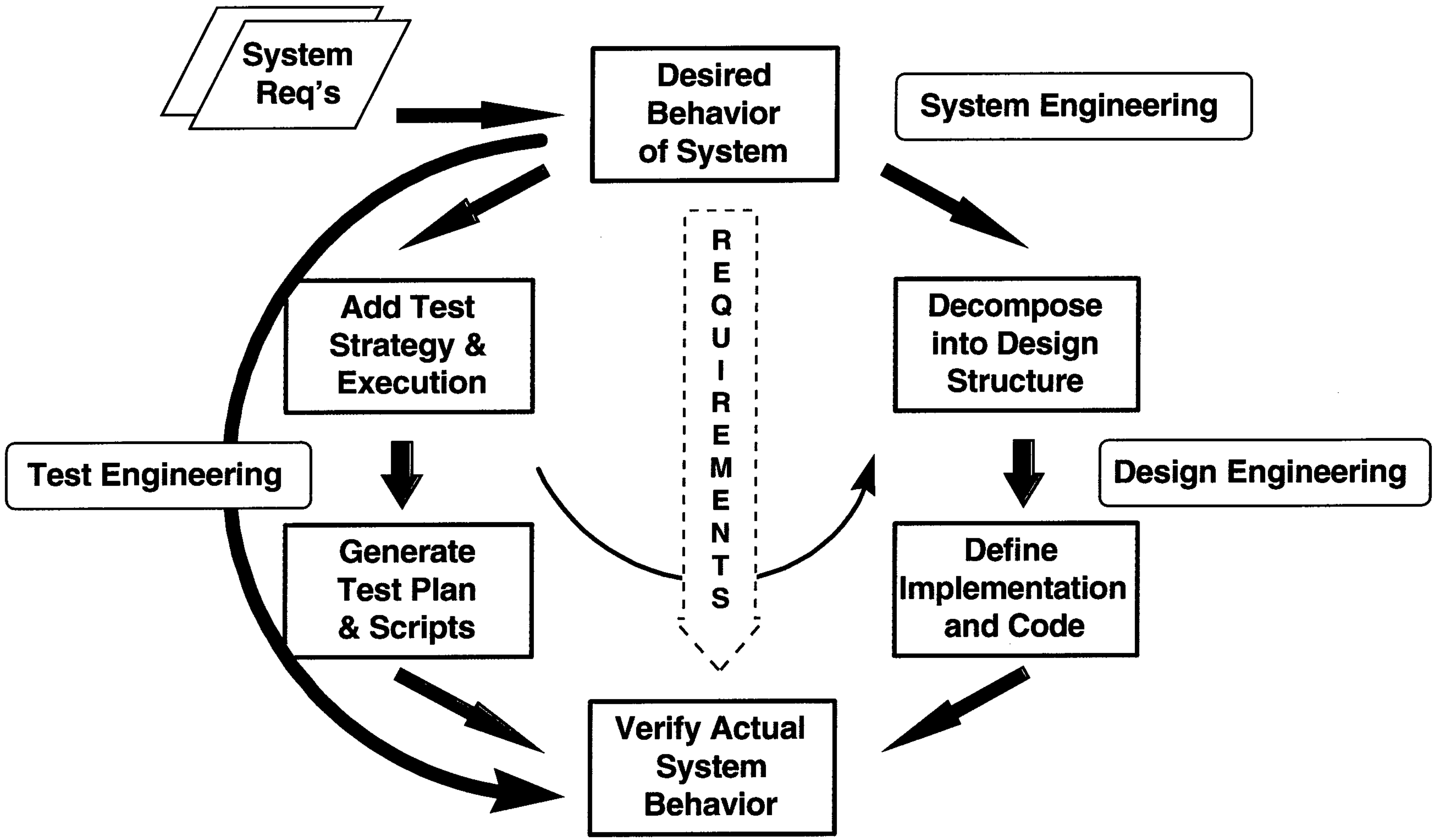
Model becomes repository for use scenarios

Scenarios can be generated for the specific needs of each stage in the process

Deliverables can be synthesized from model or paths [MSC's, use cases, test plans...]

TERADYNE
Software & Systems Test

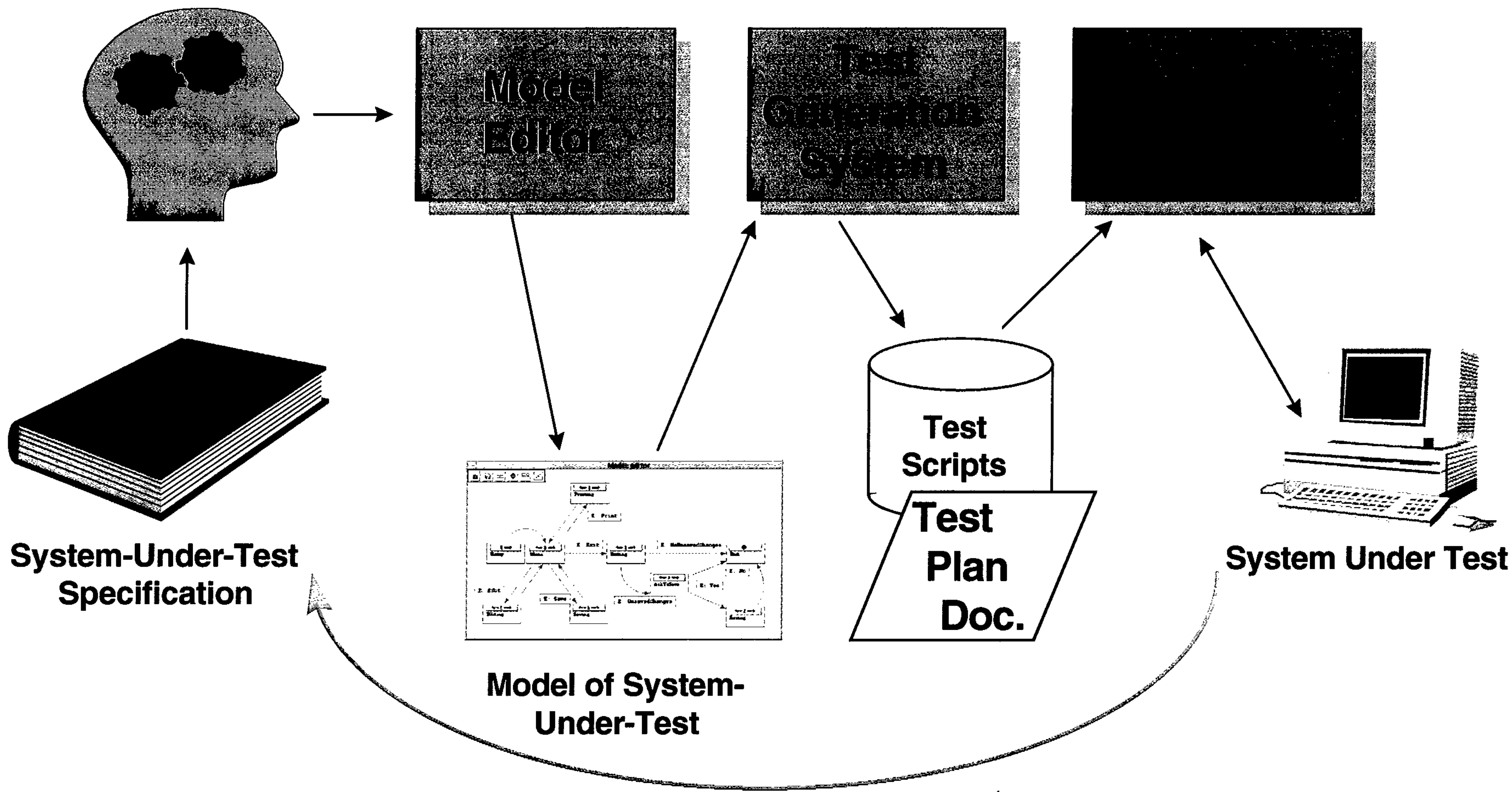
A Behavioral Model Facilitates an Integrated Design and Test Process



Slide 6 Rev 10-98

TERADYNE
Software & Systems Test

A Model Based Incremental Test Development Process



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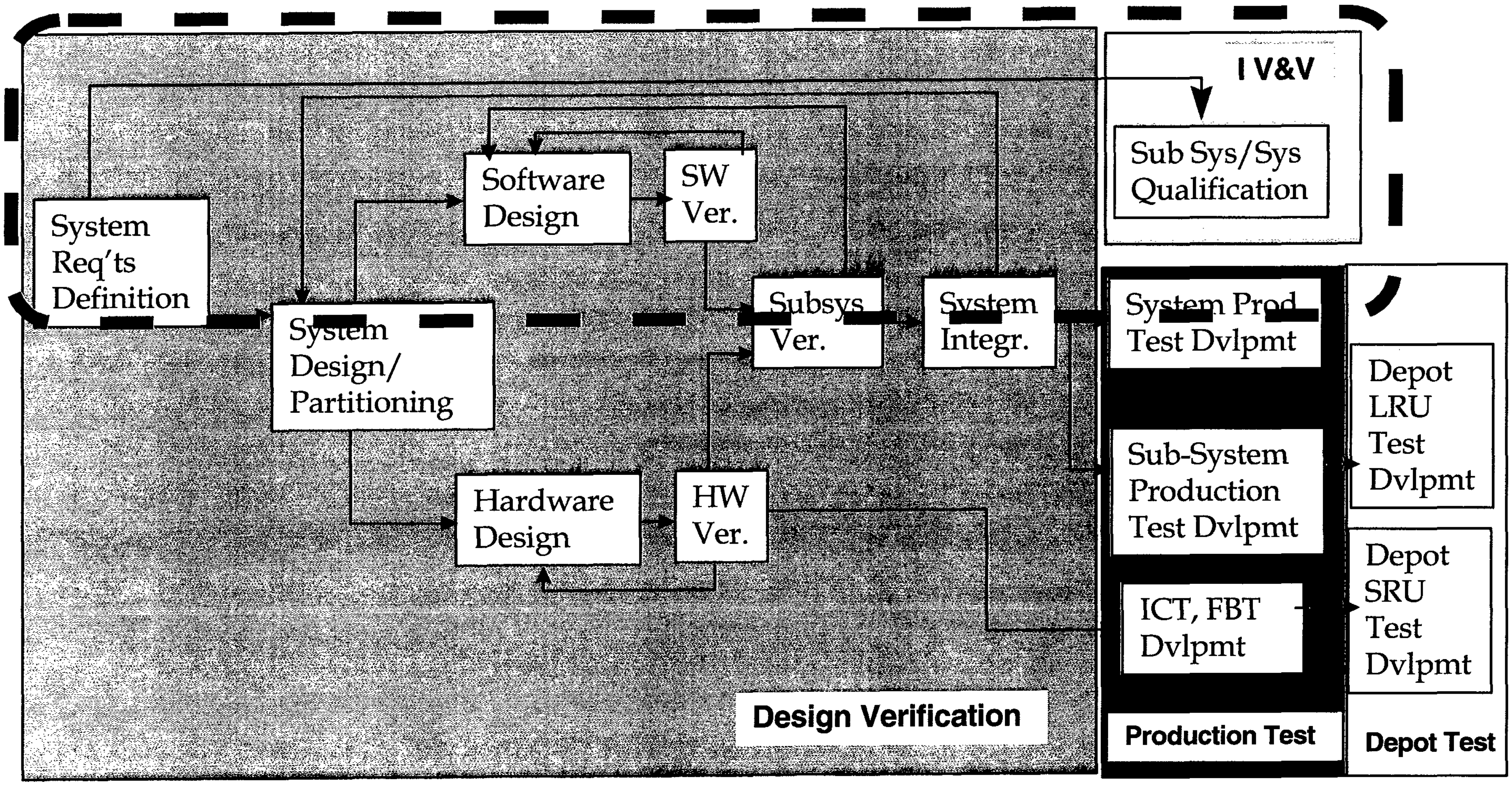
TERADYNE Software & Systems Test

Model Based Test Generation Is More Efficient for Both Design & Test Engineers

- <u>No</u> additional information is required for model based approaches
- Behavior defined once and <u>permanently</u> captured in model
- Models are reused multiple times in the product development process
- Models (and Tests) are built incrementally
- Process is self-documenting

TERADYNE
Software & Systems Test

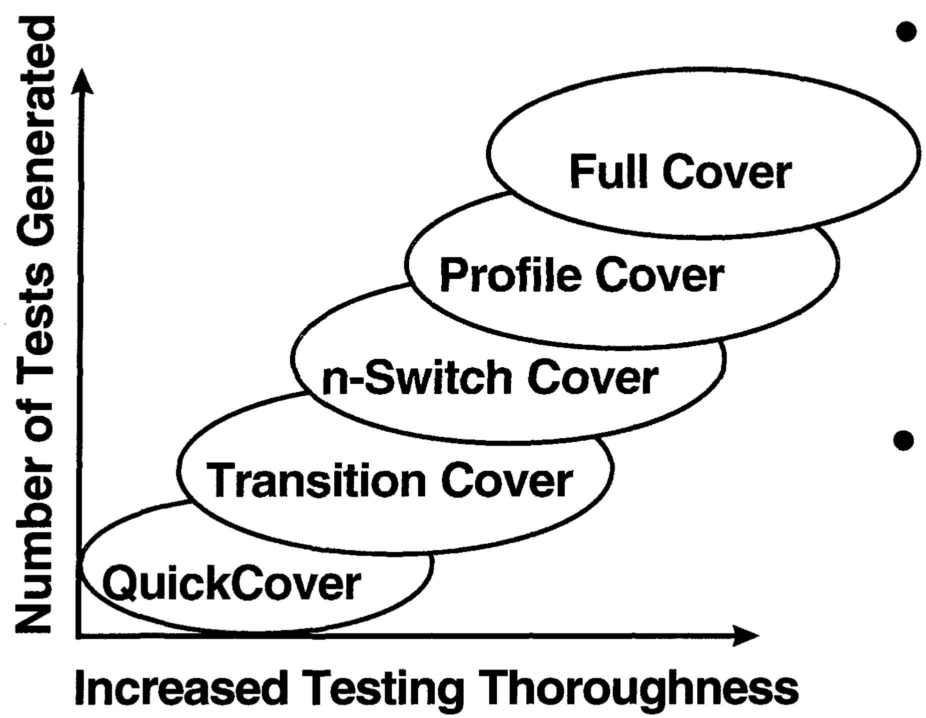
TestMaster Applies Across the Full Breadth of System Development



Source: "Transition from Development to Production", DOD R&D publication; Reviews with Raytheon, Boeing

TERADYNE Software & Systems Test

A Single Model can Create Multiple Test Suites



- Once Captured a Model is a Source of Tests for All Aspects of the Testing Process
- Each Test Generation Algorithm will Create a Suite Targeted at a Particular Goal

TERADYNE Software & Systems Test

Summary

- **High Reuse, Standard Models**
  - Incremental Development
  - Rapid Response to Change
  - High Productivity
- **Reduced Time to Market @ Known Quality**
  - Concurrent Design and Test
  - Trace-ability to Requirements
  - Flexible Test Generation Options

Sustainment of Mission Critical Electronic Warfare Software: A Systems Engineering Approach

Ches Rehberg

WR-ALC/LNEX

Warner Robins Air Logistics Center / Electronic Combat Product Group

Purpose

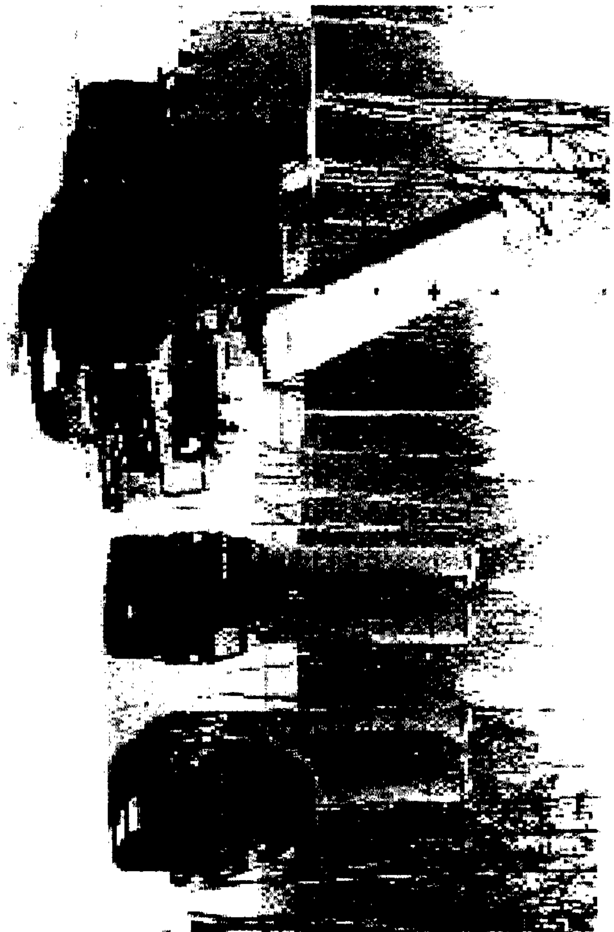
- Discuss the support of embedded software using a systems engineering approach, for a critical military application domain
- Present observations from an organizations that has provided that support for over two decades

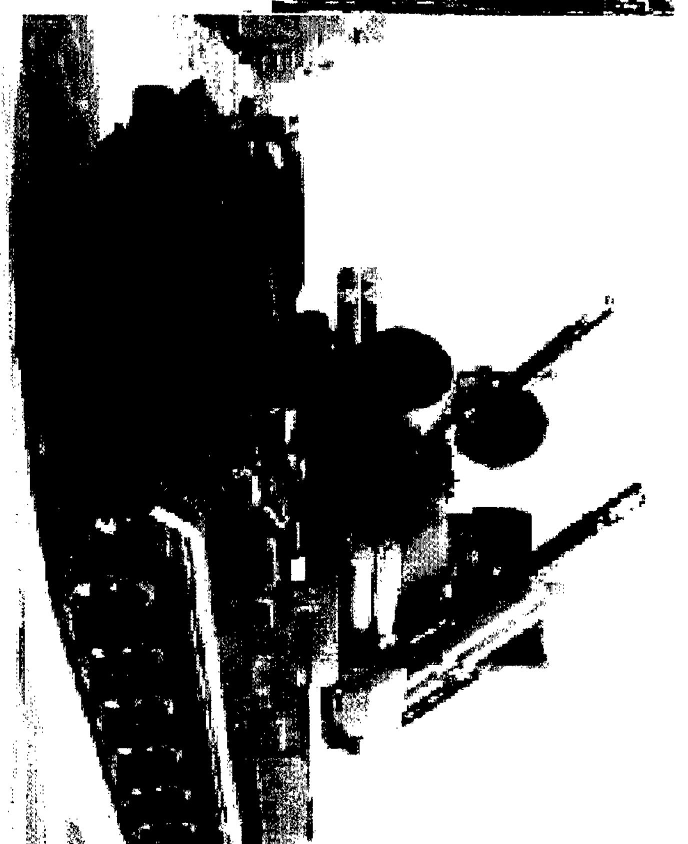
Outline

- The EW Mission and Products
- The EW Challenge:
  Continuous Change
- EW Systems Engineering
- Software Engineering in a Systems Engineering Context
- Lessons Learned

The EW Mission

Increase Aircraft Survivability



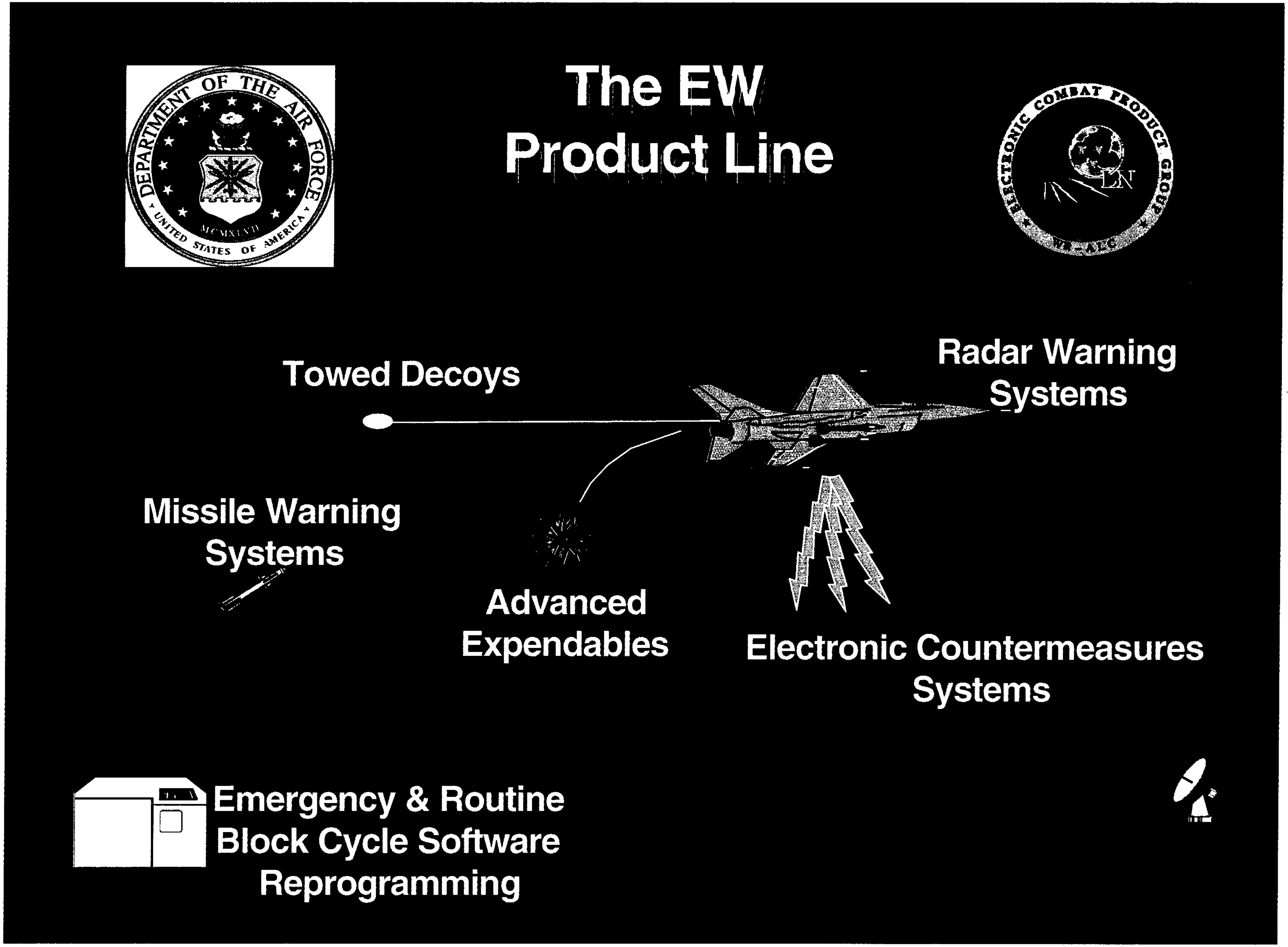


Aircraft Survivability

- Warning Functions
  - Detect and ID Radar and EO/IR Based Threat Air Defense Systems, Warn Aircrews, Cue Countermeasures
    - Radar Warning and Panoramic Receivers
    - Missile Warning Systems

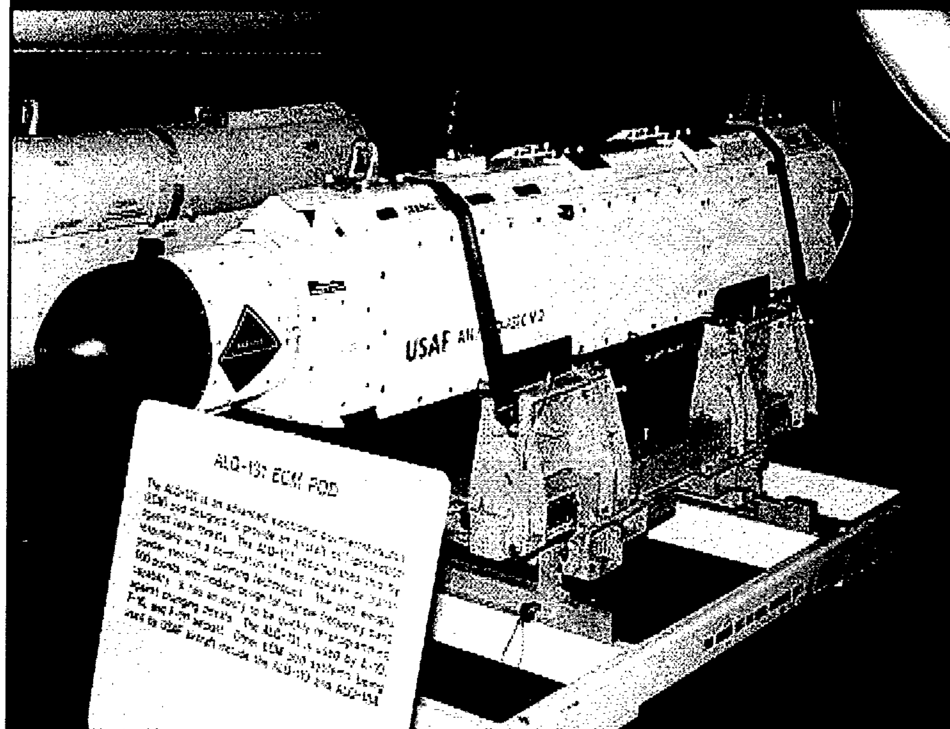
Aircraft Survivability

- Countermeasures Functions
  - Prevent Successful Detection, Acquisition, Tracking, and Engagement of Host Aircraft
    - RF Countermeasures
    - IR Countermeasures
    - Chaff and Flare Dispensers



The EW
Product Line
DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII
ELECTRONIC COMBAT PRODUCT GROUP
Towed Decoys
Radar Warning
Systems
Missile Warning
Systems
Advanced
Expendables
Electronic Countermeasures
Systems
Emergency & Routine
Block Cycle Software
Reprogramming

Electronic Countermeasures Pod



Integrated EW Suite

The EW Product Line

- Required functionality highly dependent on detailed threat characteristics:
  - RFs, pulse train details, antenna scans, other discriminants; missile and background signatures
  - Tracking and guidance receiver and control loop design
- Highly software intensive, many languages
- Complex algorithms
- Complex hardware implementations
- Infrequent major hardware upgrades

Outline

- The EW Mission and Product Line
- The EW Systems Engineering Challenge: Continuous Change
- EW Systems Engineering
- Software Engineering in a Systems Engineering Context
- Lessons Learned
-

The EW Challenge: Continuous Change

- EW system functionality requirements change drivers
  - Threat-Related Changes
    - Threat Modifications
    - Improved Knowledge of Critical Threat Characteristics
    - Countermeasures Technique Changes
    - New Threats
    - Theater-Driven Changes
  - Ops Requirements/Employment Changes
  - Integration with other On-Board Systems

The EW Challenge: Continuous Change

- Solutions:
  - Acquire new EW system
  - Design hardware modifications, retrofit existing EW system
  - Change operational tactics/usage
  - Allocate system functional changes to software and reprogram accordingly
    - System software (Operational Flight Pgm)
    - Mission data

Outline

- The EW Mission and Product Line
- The EW Challenge: Mission Induced Obsolescence
- EW Systems Engineering
- Software Engineering in a Systems Engineering Context
- Lessons Learned
-

EW Systems Engineering

- What is the "system"?
  - EW receiver and transmitter h/w and s/w, controls and displays
  - Threat air defense system
  - Avionics interfaces and aircraft wiring/cabling
  - Operator
  - Maintainer
  - Support equipment h/w and s/w
  - Reprogramming processes/support structure
    - System software
    - Mission data

EW Systems Engineering

- Systems engineering processes
  - Translation of operational requirements to technical requirements
  - Decomposition of requirements to successively lower levels of system
  - Test requirements development
  - Translation of requirements into design
  - Test and integration of lower level products leading to system solution
  - Project management
  - Configuration control

EW Systems Engineering

- Processes and products
  - Mission and threat analysis
  - Requirements development/translation/allocation
  - System performance characterization
  - Problem re-creation/diagnosis
  - Modeling and simulation
  - System acquisition and modification
  - Test and evaluation
  - Rapid and routine software reprogramming

EW Systems Engineering

- Electronic Warfare Avionics Integration Support Facility (EWAISF)
  - Engineers and computer scientists
  - Live mockups of supported EW systems and cockpit control subsystems
  - Software support environments
  - Large scale dynamic simulations of dense threat environments at microwave frequencies
  - Avionics interface simulations
  - System and subsystem modeling tools
  - Anechoic chambers and screen rooms
  - Comm and intel support structures

Outline

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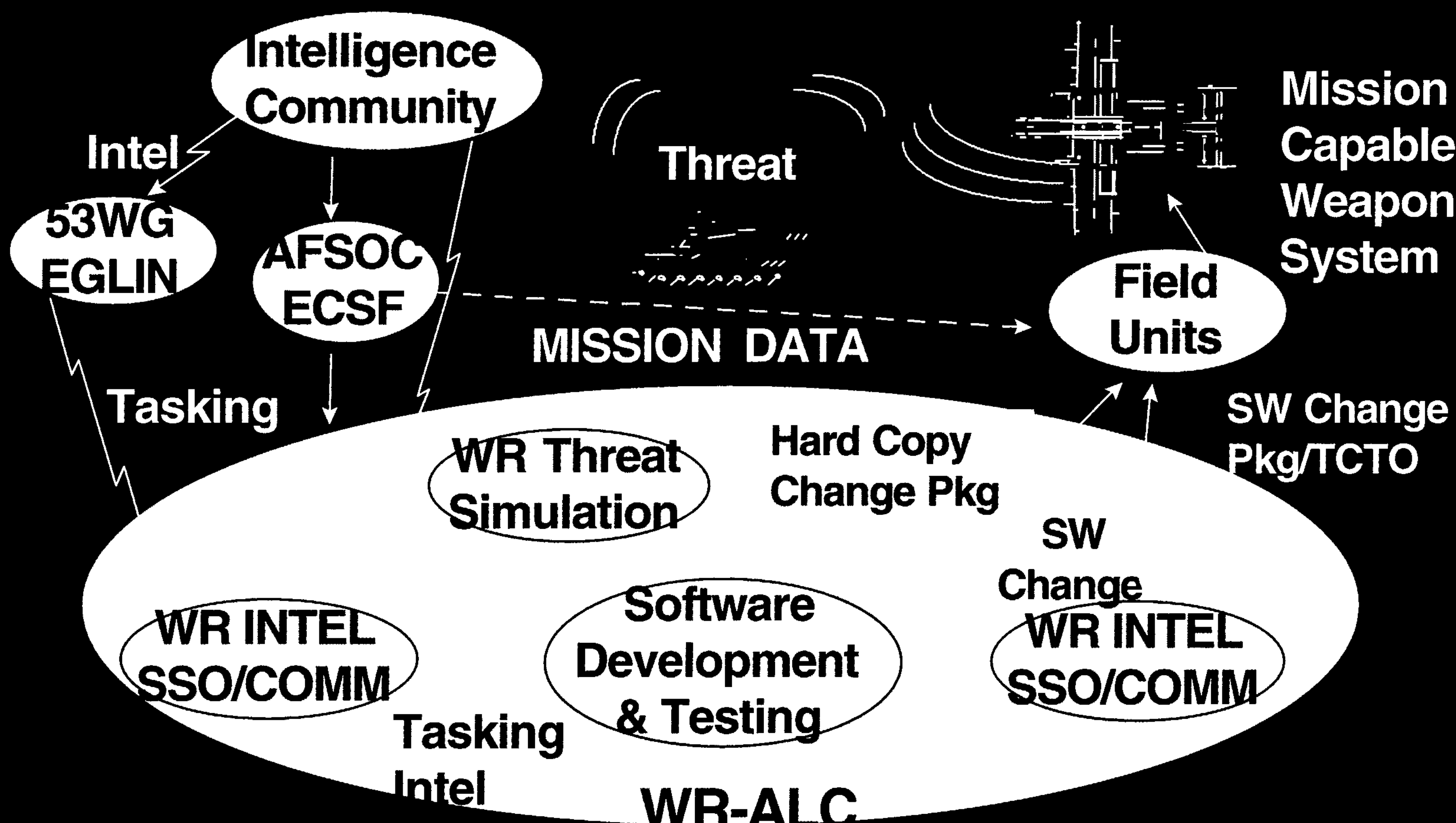
EW Software Engineering



Emergency Reprogramming + Routine Block Cycle Updates

EW Software Engineering

- Critical process structures
  - Air Force Instruction 10-703
    - Governs entire process from intel through distribution and installation
    - Specifies emergency, urgent, routine responses
  - EC PGM Operating Instruction 10-3
    - CMM-based instruction governing all aspects of EC PGM software processes

EW Software Engineering

- Critical process activities
  - Customer requirements definition
  - System analysis
  - Allocation of rqmts to software
  - Design, code, debug, test, integration
  - Independent test
  - Customer test
  - Distribution
  - Project management/config ctrl/quality

EW Software Engineering

- Mission Data Reprogramming Concept
  - Allocate user reprogrammable tables in software
  - Provide user an interactive mission data tool
  - User reprograms system as needed
    - Simple numerical threat parameters
    - New threats
    - Change in threat priorities

Outline

- The EW Mission and Product Line
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Lesson 1

- Software support of a system built around an embedded computer is a systems engineering task
  - System requirements determination
    - Allocation of functions to software
      - Design/code/test of software
  - Integration of software in the system
  - System level test of modified software

Lesson 2

Software will change!

Lesson 3

- System reprogrammabiilty must be addressed during the design phase
  - Allocation of desired functions to software
  - Partitioning of algorithms and data tables
  - Accessible electrical interfaces
  - User data/mission data reprogramming tools
  - File distribution methods
  - Processes and procedures

Lesson 4

100%
memory growth
requirements
aren't enough!

Lesson 5

- Process models and procedures are essential to success
  - Documented rqmts among ops customer, acquirer, supplier
  - Detailed plan before starting work
    - Work breakdown structure w/earned value
    - Software development plan
  - Detailed mid-management visibility of plans and status at least monthly
    - Technical status
    - Schedule/cost status per earned value
    - Risk management

Lesson 6

**Models, processes,
and structure
are essential for success
but are not substitutes
for domain knowledge.**

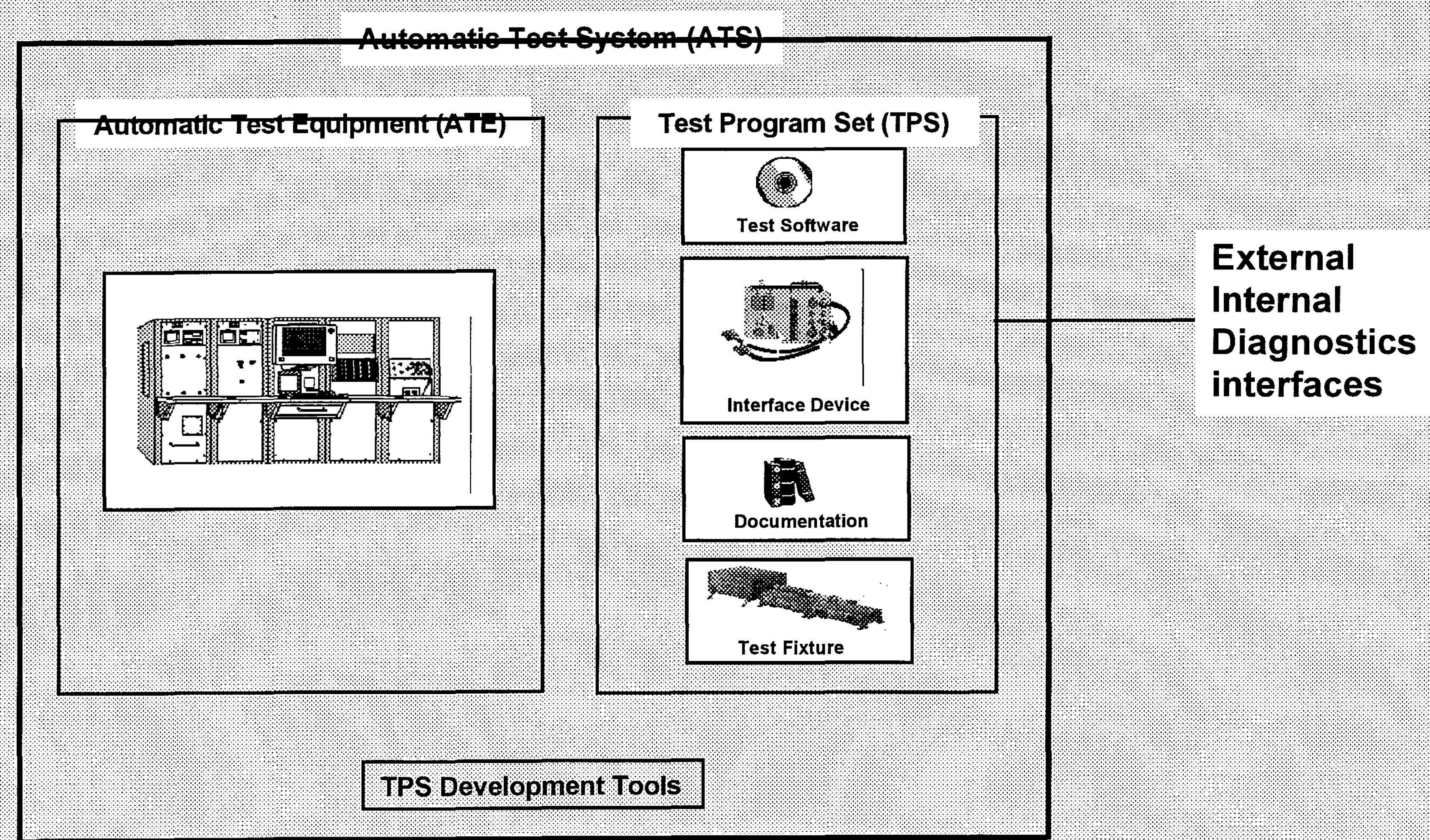
Lesson 7

- Modeling and simulation are essential
  - Requirements determination
  - Debug/problem re-creation
  - Cost savings vs. open air test
  - Test repeatability

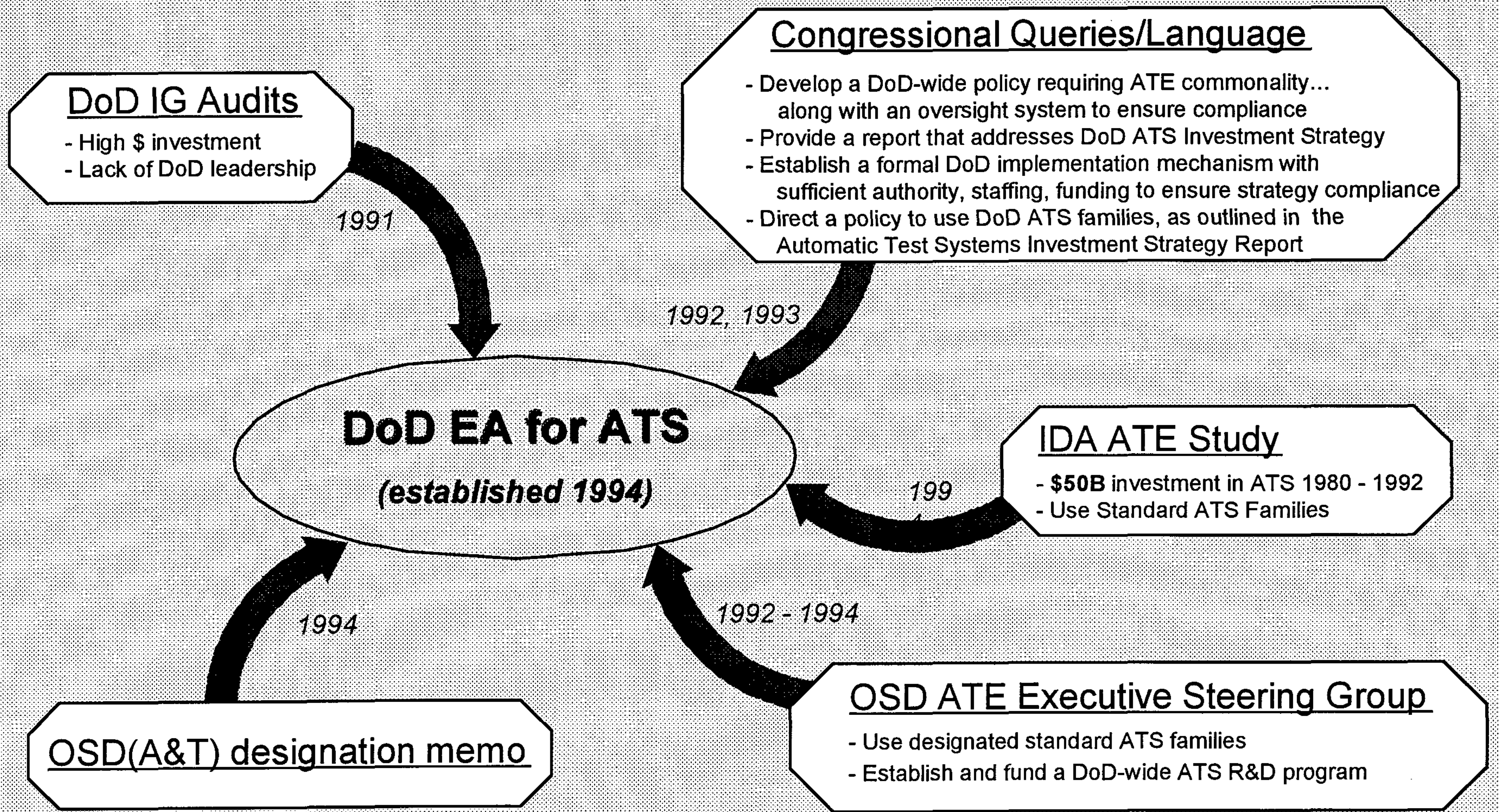
DoD
Executive Agent
for
Automatic Test Systems

Bill Ross
Assistant Director, DoD ATS Executive Agent Office

What is an ATS?



Why a DoD EA for ATS?



What Do We Do?

DoD EA for ATS

DoD 5000.2-R
para 4.3.3.4

ATS Acquisition Policy Functions

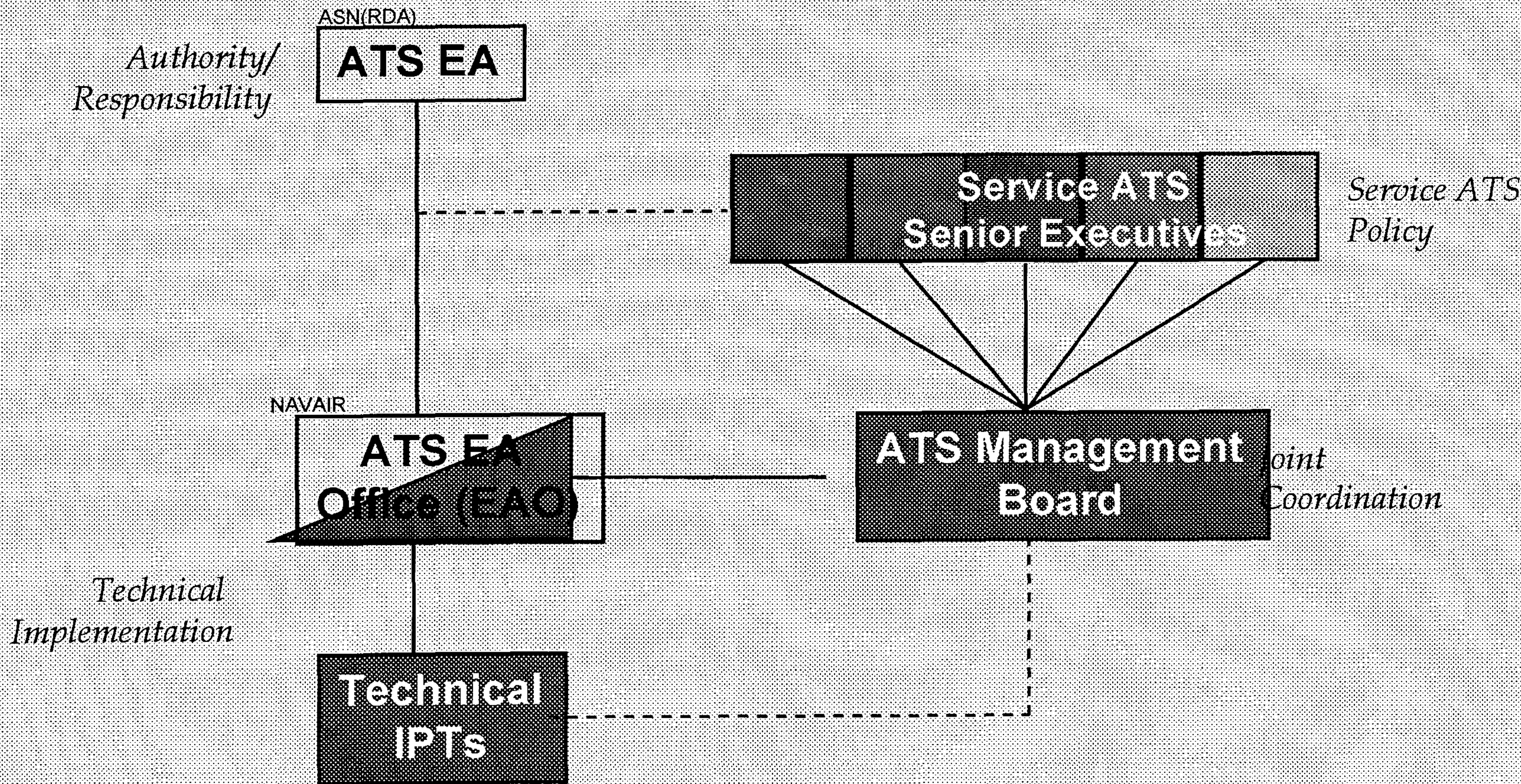
- Establish Joint implementing processes
- Monitor compliance

ATS Technology Functions

- Establish a Joint ATS R&D Program
  - Systems convergence
  - Systems modernization
  - Open Systems Approach

Customers = Weapon System Program Managers throughout DoD

Organization



What Are DoD's Goals?

- Reduce total cost of ownership of DoD ATS
-
- Provide greater flexibility to the warfighter through Joint Services interoperable ATS

13 ATS Objectives to Satisfy the Goals

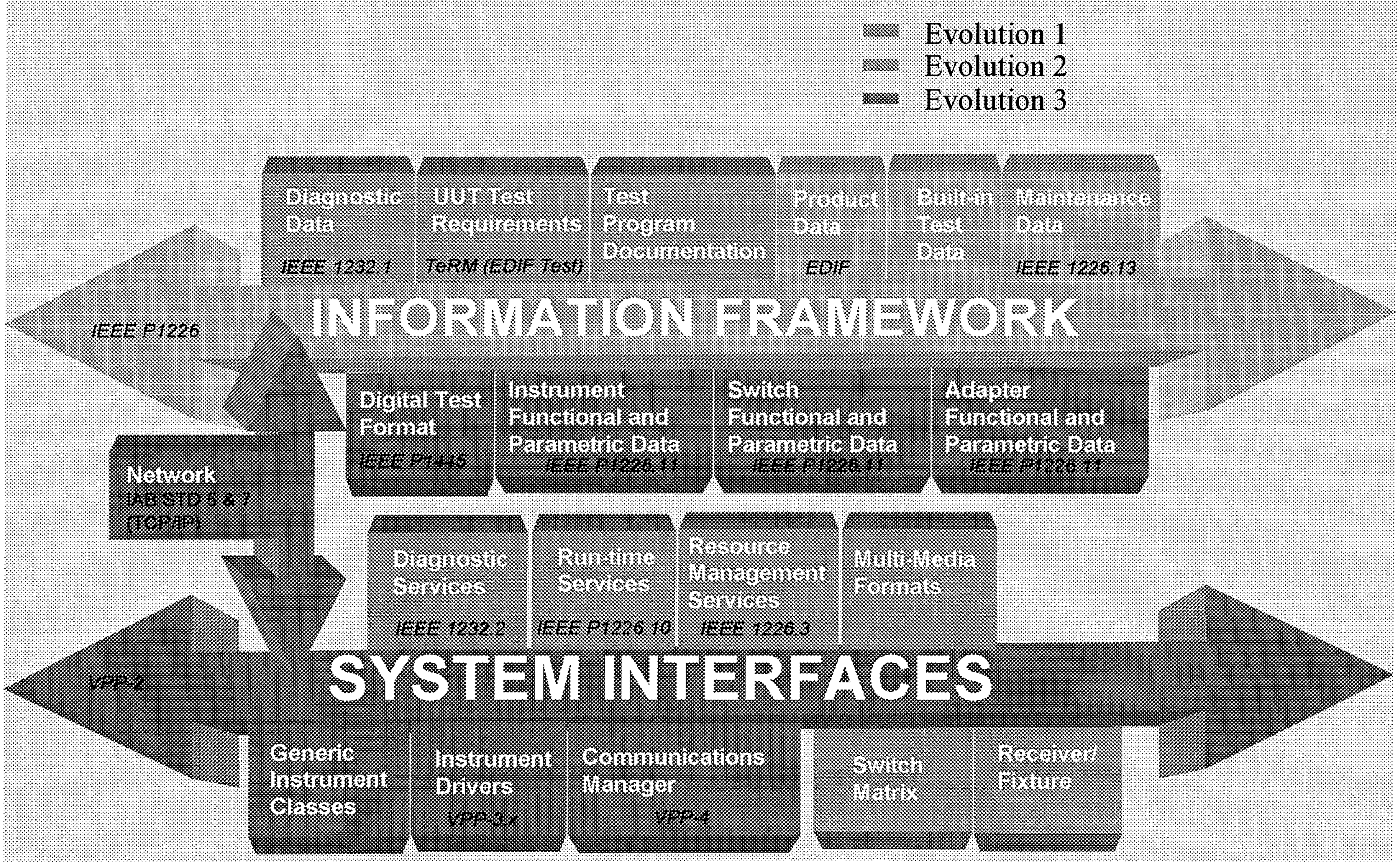
1. Improve Instrument Interchange
2. Make ATE more Scaleable with no penalty to requirements
3. Faster Technology Insertion
4. Improve TPS Rehost
5. Improve TPS Interoperability
6. Use Model Based Programming Techniques
7. Modernize Test programming Environment (Next Generation ATS Programming Environment)
8. Define a TPS Performance Specification
9. Greater use of Commercial Products
10. Capture Design-to-Test Data
11. Use Weapon System-to-Test Data
12. Use Knowledge Based TPSs
13. Define interfaces with the Integrated Diagnostics Framework

Test & Diagnostics Systems Engineering

- ATS R&D IPT (ARI)
  - Joint Services and industry team - led by ARI
  - Has been working the 13 objectives for over 3 years
  - Defined the ATS Open System Approach
- Integrated Diagnostics Architecture Study
  - 10 case studies of existing ID architectures
  - Industry/government ID workshop
  - Leveraging on work done by the ARI, recommend a course of action for an ID Open System Approach
  - Study complete end of Sept '98
- Test & Diagnostics Consortium being established

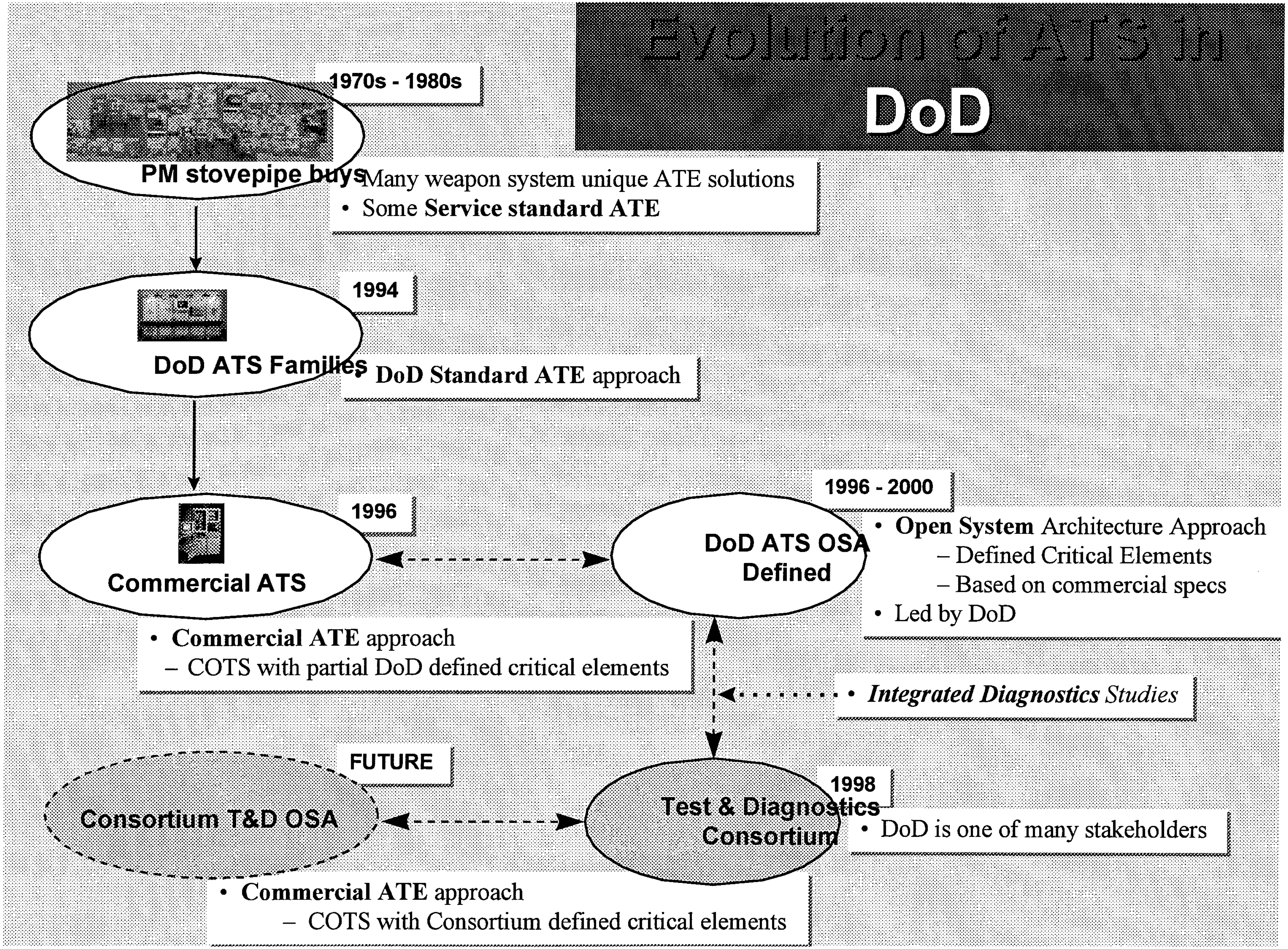
ATS Open Systems Approach

Reference Model



What is Next for DoD?

- Complete the ATS Open System Architecture and update the ATS Technical Architecture (JTA)
- Leverage on the ATS OSA to define an ID OSA
- Establish a DoD Test & Diagnostics Center of Excellence
  - Establish R&D funding
  - Integrate on-going Service T&D projects
- Participate in the Test and Diagnostics Consortium to work areas of common interest with industry


Evolution of ATS in DoD
1970s - 1980s
PM stovepipe buys
• Many weapon system unique ATE solutions
• Some **Service standard ATE**
1994
DoD ATS Families
• **DoD Standard ATE** approach
1996
Commercial ATS
• **Commercial ATE** approach
– COTS with partial DoD defined critical elements
1996 - 2000
DoD ATS OSA Defined
• **Open System** Architecture Approach
– Defined Critical Elements
– Based on commercial specs
• Led by DoD
• ***Integrated Diagnostics*** *Studies*
1998
Test & Diagnostics Consortium
• DoD is one of many stakeholders
FUTURE
Consortium T&D OSA
• **Commercial ATE** approach
– COTS with Consortium defined critical elements

DoD "Revolution in Business Affairs" *

1. <u>Implement aggressively acquisition reform initiatives</u>:
   - "Increase use of commercial practices"
   - "Greatly expanded purchase of commercially available items"
   - "Institutionalize concept of Total Cost of Ownership"
   -
2. <u>Work to bring about far greater civilian/military industrial integration:</u>
   - "Seek greatly expanded partnership with commercial industry"
   -
3. <u>Shift from infrastructure and support to modernization</u>:
   - "Reduce support costs"
   - "Capture commercial technology"
   -

* Mr. Gansler, OSD(A&T)

Dr. Patricia Sanders
Director, Test, Systems Engineering and Evaluation
Office of the Under Secretary of Defense (Acquisition and Technology)
Keynote Address
The 1st Annual NDIA Systems Engineering and Supportability Conference
September 15, 1998

Thank you, Mark, for that warm introduction. And thank you, Bob Rassa and NDIA for both sponsoring this event and inviting me to speak. I am especially pleased to see so many industry associations participating in providing a forum for a very important topic. Our industry partners are critical to the successful achievement of DoD's objectives.

This first annual NDIA Systems Engineering and Supportability Conference represents a major step since we now have both DoD and industry engineers talking about the supportability concerns that logisticians have had for many years. And I have to say that calling this the first ANNUAL conference indicates a commitment to dealing with these issues for the long haul—and it will take that kind of long term commitment.

We are seeking to improve DoD weapons systems supportability by way of effective systems engineering—not only on new acquisitions, but also on legacy systems. And because of the very direct relationship of supportability to the total cost of ownership, robust system engineering produce not only better quality weapons, but also more affordable weapons. Those of you attending this conference must recognize both the importance of supportability and the value of systems engineering to achieving it.

Background

Since the end of the Cold War we have made some very deep cuts in our national security apparatus and adjusted our force structure to meet the demands of a new and very different security environment that we see today.

At the same time that we drew down, as you all know, we also became much busier. The end of the Cold War left us with a more complex, a more

unpredictable, a more volatile world than we ever could have foreseen in the early 1990s.

In Iraq and Somalia, in Haiti and Rwanda, and of course today in Bosnia andKosovo, we have seen the face of future conflicts. Conflicts that reflect a lot of the bitter divisions of the past. In the Far East and Southwest Asia we continue to face rogue states that have some very large military capabilities, as well as some capabilities that come with chemical, biological, and nuclear weapons and the means to deliver them.

Today as we meet here, in support of our military strategy, we have about 120,000 servicemen and women deployed away from home for training or what we call named operations around the world. The level of activity that we have maintained since the end of the Cold War, as you well know, has been very challenging.

The dilemma we face right now involves competing—and seemingly unlimited--demands for constrained resources. We simply cannot afford all that we would like to do—or even all that we must do. With fixed total resources, we have resorted to "robbing Peter to pay Paul," taking from future investments in modernization to maintain current readiness. Yet we all know that we must develop the new systems needed to meet the challenges of early 21st century. And we must modernize our current equipment in order to maintain our military superiority in the face of potential adversaries, equipped off the world's commercial or military markets, and their increasing use of asymmetrical warfare.

We must simultaneously shift our focus from the traditional weapons platforms (ships, planes, and tanks) to weapons that will counter these future asymmetrical threats—such as defenses against biological warfare, information warfare, and ballistic missiles. And, on the offensive, we must increase our funding on enhanced and secure C3I and precision weapons.

We must also face the reality that, for the foreseeable future, the vast majority of the systems we will use are those that are already deployed. Because we stopped modernizing over the last decade—when our procurement account dropped by more than 70 percent—we are now spending billions, for example, to maintain an aging fleet of aircraft—75 percent of which will soon have an average age of more than 20 years. Flying

hour costs for that aging fleet have risen almost 70 percent during the past four years, and maintenance costs are skyrocketing. Worse still, the age and deteriorating state of these systems is having an effect on readiness. They demand more and more dollars to just keep them going.

Dr Gansler has characterized this as being "trapped in a death spiral." The requirement to maintain our aging equipment is costing us much more each year: in repair costs, down time, and maintenance tempo. But we must keep this equipment in repair to maintain readiness. It drains our resources—resources we should be applying to modernization of our traditional systems and development and deployment of the new systems. S, we stretch out our replacement schedules to ridiculous lengths and reduce the quantities of new equipment we purchase—raising their costs and still further delaying modernization.

Compounding the problem is the increased operational tempo required by our worldwide role as the sole remaining superpower, which more rapidly wears out the old equipment.

To break out of this cycle will be extremely difficult. It will require significant cultural change, a sense of urgency, and implementation of difficult decisions. It will not be enough simply to accept the notion of the need for a Revolution in Military Affairs and the need for a Revolution in Business Affairs. **Action now** is essential for our security in the 21st century.

Criticality of the Supportability Issues

Let me give some idea of the magnitude of the supportability issue—put it in context for you.

As an organization, one of our real challenges is to manage about 70 years of technology at any one point in time. We operate, on a daily basis, aircraft that were designed back in the early 50s and we still have to maintain them, buy spare parts for them, and keep them updated. At the same time, we are working on research and development programs for systems that won't be fielded until 2015-2020. Managing that spectrum of technology is a real challenge.

Fully one-third of the DoD budget (about $80 billion per year) and nearly half of the Department's manpower (1,250,000 military and civilians) is in Logistics. To get some perspective on that, in the active military we have 290,000 personnel in the combat forces and twice that number of active military in the logistics force.

If we examine what happened from 1988 to 1998, procurement dollars fell by more than 70 percent. Operations and maintenance on the other hand, reduced only 16 percent. On a per troop basis, operations and support costs actually grew from $107K to $125K per troop.

In *The Art of War*, Sun Tzu estimated that 60 percent of military spending is required to cover broken down chariots, worn out horses, armor, arrows and crossbows, supply wagons and other support costs. Things haven't changed much. While the weapons are different, the high cost of maintaining them isn't. The Navy, for instance, estimates 64 percent of the lifetime costs of a surface combatant ship can be attributed to operation and support.

This picture is not improving. Consider in the 1970s, operations and support costs typically accounted for up to 60 percent of a systems total life-cycle costs. For many reasons, not the least of which being that weapon systems as general rule are remaining in the DoD inventory much longer than originally planned, the O&S costs as a percentage of total life cycle costs have been steadily increasing to the point where they are now estimated to be closer to 72 percent.

Relationship between Acquisition and Logistics

This adds up to a very real and very substantial shared challenge for the acquisition and logistics communities.

Now consider that for all our systems, both new and legacy, a significant portion of O&S costs is directly attributed to the design decisions made during the early phases of the acquisition process. The major categories of cost drivers include fuel and other expendables, spares—both initial and replenishment, operating personnel, and both maintenance and repair labor—with people being the largest element. But all factors that are influenced very early in the acquisition process. And this is one of the places

where the acquisition and logistics community must come together to face the challenges.

Success will occur when our different, but complementary, approaches and perspectives are brought together. The final value added is then greater than the sum of the parts. Without a doubt, the most essential tenet of Integrated Product and Process Development (IPPD) is multidisciplinary teamwork.

On the acquisition side, our multifunctional IPTs now include Logisticians as key players on the product development team - providing the logistics community with the opportunity to make sure that supportability considerations **are** an integral part of the design and development processes from the very start. A major challenge for the Logistician is the ability to bring supportability and logistics issues of substance "to the table" in a way that all IPT participants can understand, appreciate and successfully resolve.

Having aggressively brought the Acquisition Logistician into the development process earlier we can address sustainment issues during system design where ninety percent of the cost of owning a weapons system is determined. Where they can have an impact on increasing fuel efficiency, reducing the consumption rates of expendables like ammunition, more reliable and durable spares, design for ease of repair, reduced size and weight, and very importantly system designs that decrease the number of operations and support personnel.

Let's consider aircraft as a example. The next generation of military aircraft, may be faster, fly farther, use less fuel, and be much lighter. The next generation of military aircraft will also require more power for more sensors and weapons systems. The number of electric motors on board an aircraft has risen dramatically over the past 20 years as fly-by-wire systems have been introduced. At the same time, systems are becoming increasingly reliable. In general, there is a move away from numerous, separately specified system components to integrated networks.

Traditionally, aircraft electrical systems have been designed on a centralized basis, with generators supplying power to a power center that then distributes it to the aircraft's systems. In a distributed, or integrated, architecture, the long runs of individual power wires are replaced with

secondary power feeders linked to multiplexed data bus lines. The integrated network eliminates components and wires; reduces weight, installation, and testing times; and increases reliability.

According to some manufacturers' figures, with use of distributed power systems, the number electrical components can be cut by 35 percent, wire segments by 40 percent, weight by 40 percent, and installed time by 60 percent. In addition, reliability can be improved by 20 percent. A win-win-win situation for acquisition, logistics, andwarfighter.

NAVAIR, for legacy systems, has been able to break down major cost categories to 136 discrete cost elements and identify internal and external factors that influence them. This has helped managers target areas for cutting costs.

But only through detailed analysis of weapons systems and by documenting how weapons wear, the cost of repairing individual parts, etc., will we be able to manage total ownership costs. You have to break down very complex systems to determine where a small investment can have a high payoff.

So far, NAVAIR has identified savings of $404 million over a five-ear period by adopting logistics reengineering proposals to make design improvements on items with high cost and high failure rates.

The challenge will be to make those initial investments that could reap long-term savings. This is very difficult when you are living hand-to-mouth. Higher costs today are hard to sell for promised savings tomorrow.

This is why we must treat life cycle costs as an independent variable-something that is consciously considered up front in the design process and giving it an "equal place at the table" along with system performance. Something that gets the focused attention of the Joint Requirements Oversight Council (JROC). Something that we hold program managers accountable for.

The Defense Science Board has estimated that the return on investment for designing in supportability can be 3-5:1. And we can cite the LPD-17 example where an investment of approximately $28 million per ship can

result in a 20 percent reduction in total ownership costs or about $4 billion over fleet lifetime.

The Open Systems Approach

One of the ways we can design with life cycle considerations in mind is the open systems approach which is both a technical approach and a preferred business strategy.

With an open systems approach, program managers can have access to alternative sources for the key subsystems and components to construct DoD systems. DoD investment early in the life-cycle is reduced since at least some of the required subsystems or components are likely to already be available, or being developed without direct DoD dollars. Production sources can be competitively selected from multiple competitors.

The system design flexibility inherent in the open system approach, and the more widespread availability of conforming commercial products, mitigates potential problems associated with a diminishing defense-dependent manufacturing base. Finally, life-cycle costs are reduced by a long-lived, standards based architecture that facilitates upgrades by incremental technology insertion, rather than by large scale system redesign.

If we had used an open systems approach to designing the B-52, I wonder how much we could have saved as we constantly evolved that aircraft over half a century to take on missions unthought of when it was first conceived!

Legacy Systems

With the number of "new starts" sharply declining, the real "target of opportunity for DoD budget savings lies not with new systems, but with the large number legacy systems now in the DoD inventories. Basically we need to approach the issue of our legacy systems similar to the way we now develop and acquire our new systems, subjecting upgrades and modifications to the same kinds of cost, performance, and schedule trade-offs, again treating cost as an independent variable. The principles of IPPD which we now successfully employ in the development and acquisition of new systems need to be applied equally to mods and upgrades as well.

For these systems, we need a business and engineering revolution similar to the one we have been experiencing in the acquisition community. We need to attack the O&S cost issues on a number of fronts. Not only do we need to apply systems engineering principles to our weapons systems, we need to apply systems engineering principles to our logistics infrastructure. Again, an acquisition-logistics partnership.

There are great economies to be gained from re-engineering and modernizing the DoD logistics infrastructure. We already have major changes underway in this arena, and shortly we'll be hearing from Mr. Lou Kratz who is heading up our Logistics Reengineering and Modernization effort. I will leave it to Lou to tell you about all the things we are doing now and intend to do in the near future to reengineer and modernize DoD's logistics. These changes hold great promise in further helping to lower the cost of supporting not only the legacy systems but also our future systems.

Summary and Closing

As I close I would like to reemphasize my message to you:

- Modernization of our forces must take place—and it must take place within the existing budget constraints.

- We must lower logistics costs before the tail totally consumes the tooth.

- There are no simple solutions to lowering total ownership costs.

- O&S costs on our legacy systems represent a large target of opportunity that we must exploit.

- The same focus and commitment we applied to acquisition reform initiatives—IPPD, cost as an independent variable, open systems approaches--need to be carried over to thesustainment and in-service engineering arenas.

- We must break down the "walls or stovepipes" that separate the acquisition and logistics communities if we are to be successful

Listen closely to what LouKratz has to say about what the logistics community is doing hand-in-hand with the acquisitions community in terms of a business revolution to reduce the costs of the logistics infrastructure.

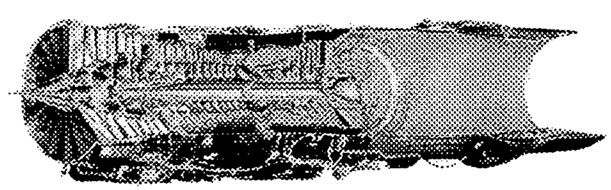
Together we will have discussed a number of strategies or initiatives that I believe will contribute to engaging our shared challenges. Undoubtedly these strategies and others will be discussed in more detail here this week.

Because of the unprecedented opportunities and challenges emerging from a rapidly changing world, I cannot emphasize too much our need to work together to succeed. We must rely on each other now more than ever before. If we join our talents and work together, we can and will meet those challenges.

Neither in DoD nor industry, none of us is as smart as all of us.

Reliability Centered Maintenance (RCM) on USAF Gas Turbine Engines

NDIA Conference, Sept. 16th 1998



R. L. Scott / ASC/ LP

TOPICS

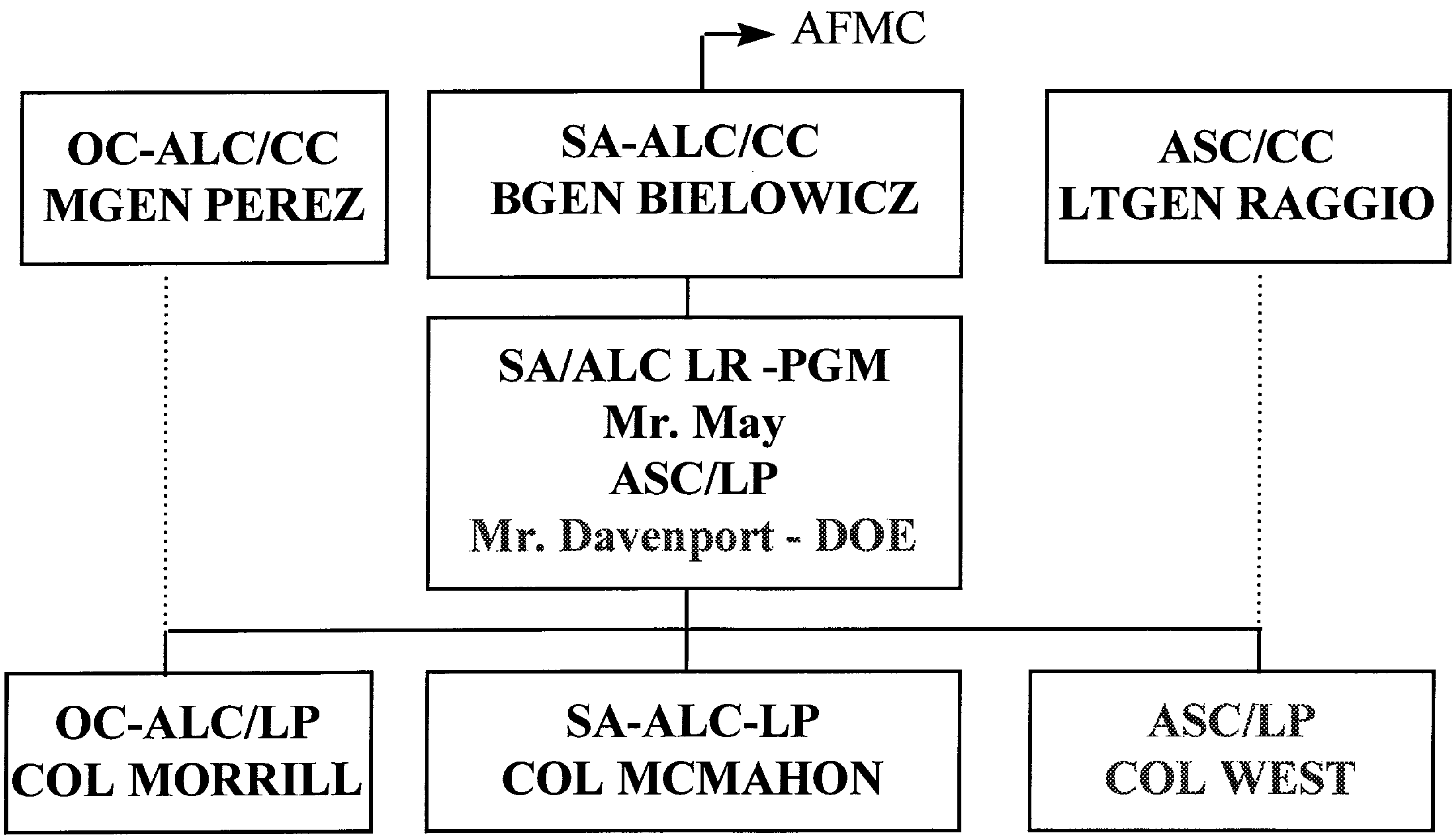
Propulsion DSO

- **Introduction**
- **What is RCM / RCM History**
- **RCM vs OCM in Engine Maintenance Planning**
- **F100-PW-220/E RCM Demonstration at Luke AFB**

INTRODUCTION

Propulsion DSO

USAF Propulsion Product Group- Organization



INTRODUCTION

- ***DSO MISSION***
- **DEVELOP, ACQUIRE, FIELD, AND SUSTAIN AFFORDABLE AND SUPERIOR ENGINES IN SUPPORT OF OUR CUSTOMERS REQUIREMENTS**
- ***DSO GOAL***
- **BECOME THE DEPARTMENT OF DEFENSE SUPPLIER OF CHOICE FOR THE WORLD'S BEST PROPULSION SYSTEMS**

INTRODUCTION

Current USAF Propulsion DSO Programs

Engine	Aircraft	ASC/LP IPT
F119-PW-100	F-22	LPR
F100-PW-229	F-15/F-16	LPP
F100-PW-129	F-16	LPP*
F118-GE-100	B-2	LPB
F118-GE-101	U-2	LPB
F117-PW-100	C-17	LPC
FMS Engines	F-15/F-16	LPX
JSF		LPD

* Transferred to OC-ALC in June 98

WHAT IS RCM ?

DEFINITION

"A disciplined logic or methodology used to identify preventative maintenance tasks to realize the inherent reliability of equipment at the least expenditure of resources."

Or...

"Fix what is broke and what may break within the next service interval."

Or...

"Preventative Maintenance"

HISTORY OF RCM

- **Original Maintenance Philosophy of Jet Engines - Max Overhaul Time - MOT**
  - Based on a philosophy that every mechanical system has a right MOT
  - Initial MOT limits were not analytically based
  - Significant efforts applied to growing specified MOT
    - Used sampling of reliability data and analytical teardown of extended time engines
  - Ultimate Conclusion
    - Most items had no right overhaul time
    - MOT gave up component life
    - Statistical analysis showed no change in safety or reliability when MOT limits changed

HISTORY OF RCM

- **MOT Gave Way to an "On Condition" Maintenance Philosophy**
  - Physically inspect for failures at predefined intervals
  - All parts reach more of their inherent reliability
- **"On Condition" Could Not Predict Many Hidden or Complex Failure Modes**
- **Led to Unanticipated Consequences and Unanticipated Equipment Down Time**

HISTORY OF RCM

- **Reliability Centered Maintenance**
  - Born out of joint FAA and Airline Association Maintenance Steering Group (MSG) to develop initial maintenance program for the 747 aricraft
  - Put forth a series of logic paths that systematically reviewed the aircraft's design so that the best maintenance process could be used for each component or system
  - Sorted out potential maintenance tasks and then evaluated them to determine which must be done for safety, hidden failures or economic benefit
  - Also combined scheduled tasks with condition monitoring and "on condition" maintenance

HISTORY OF RCM

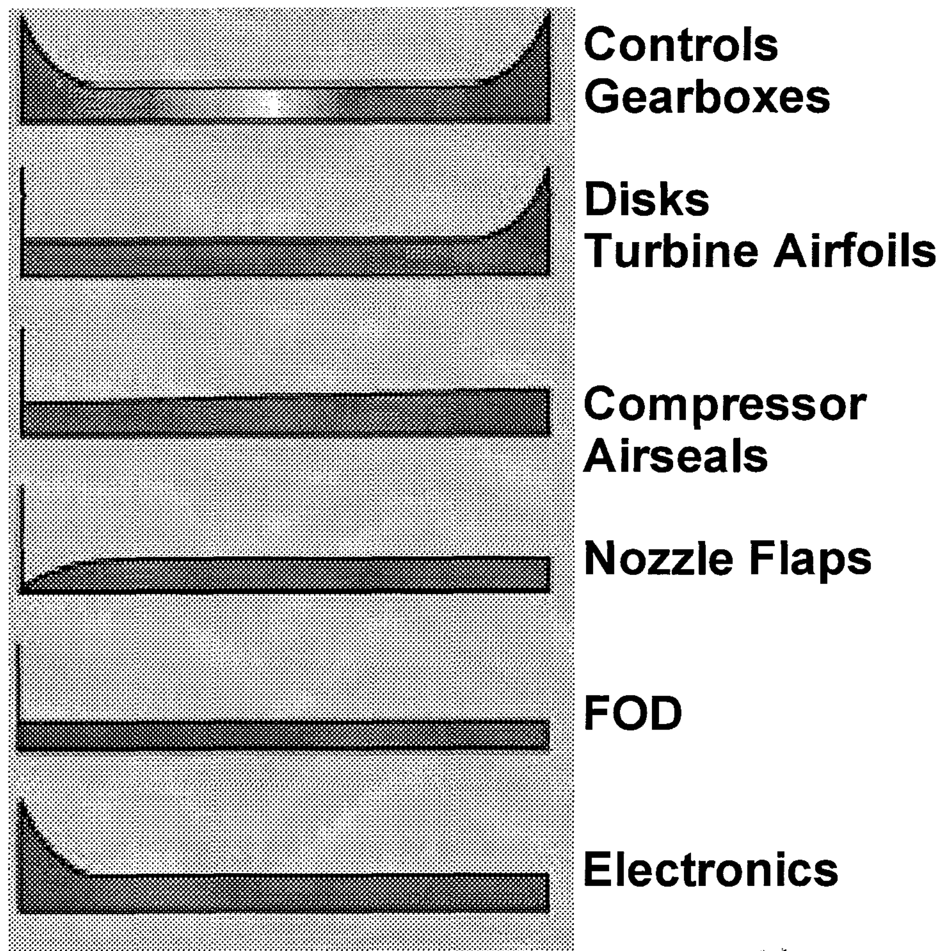
- **MSG 2 - Refined the RCM Process**
  - Applied to the initial maintenance plans of the DC10 and L1011
- **MSG 3 - Refined the Process Further**
  - Strengthened the process (feed back loop) for constantly reevaluating maintenance programs
    - RCMA - Reliability Centered Maintenance Analysis
    - Needed as experience was gained and as the system ages
  - Application to pre-existing systems

OCM VERSES RCM in ENGINE MAINTENANCE PLANNING

Propulsion DSO

- **"Routine maintenance is about avoiding, reducing or eliminating the consequences of failures"**
  - RCM gives preference to planned maintenance
  - OCM gives preference to unplanned maintenance
- **"It is nearly always more cost-effective to try to improve the performance of an unreliable asset by improving the way it is operated and maintained..."**
- **RCM is USAF Policy**

Patterns of Equipment Failure



OCM VERSES RCM in ENGINE MAINTENANCE PLANNING

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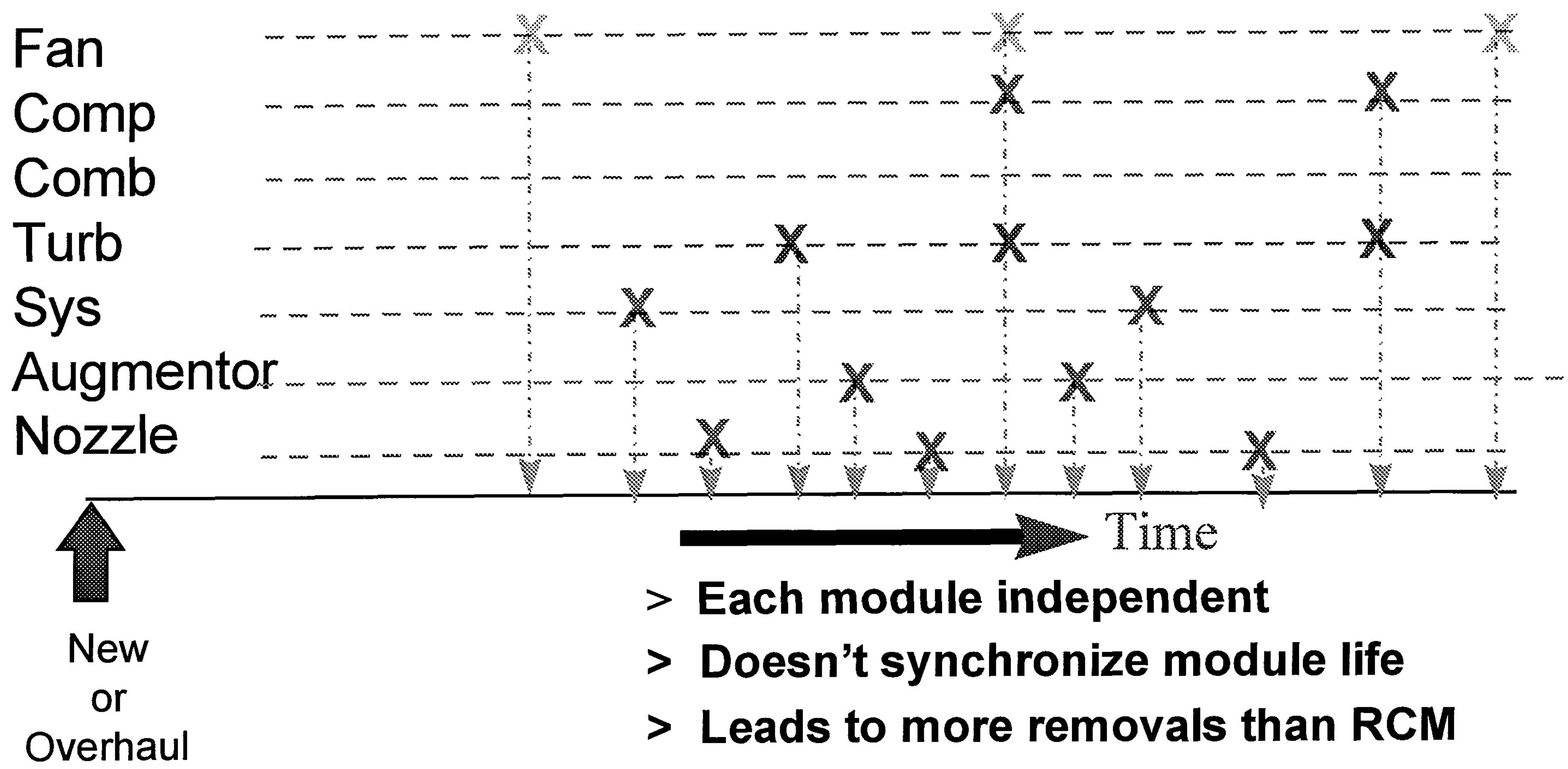
TYPICAL USAF PRACTICE



> Each module independent

> Doesn't synchronize module life

> Leads to more removals than RCM

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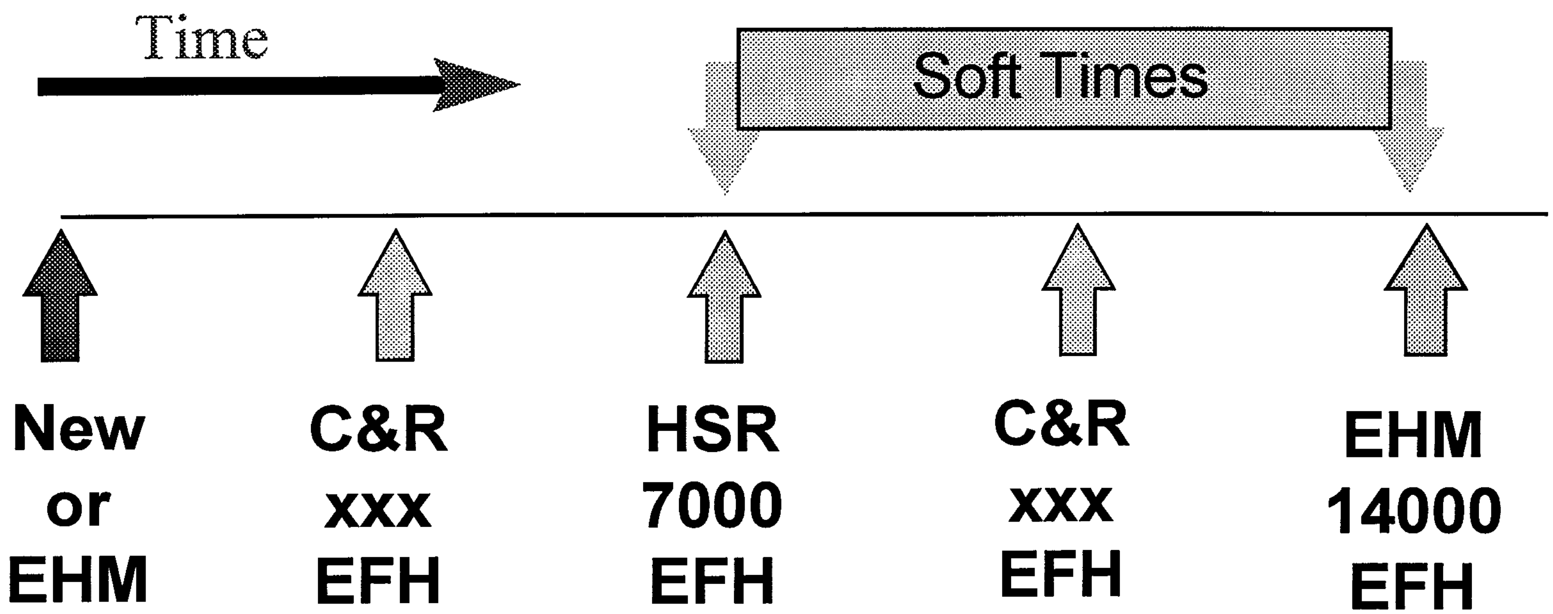
RCM in COMMERCIAL PRACTICE

Propulsion DSO

RCM: Achieve inherent reliability via planned maintenance



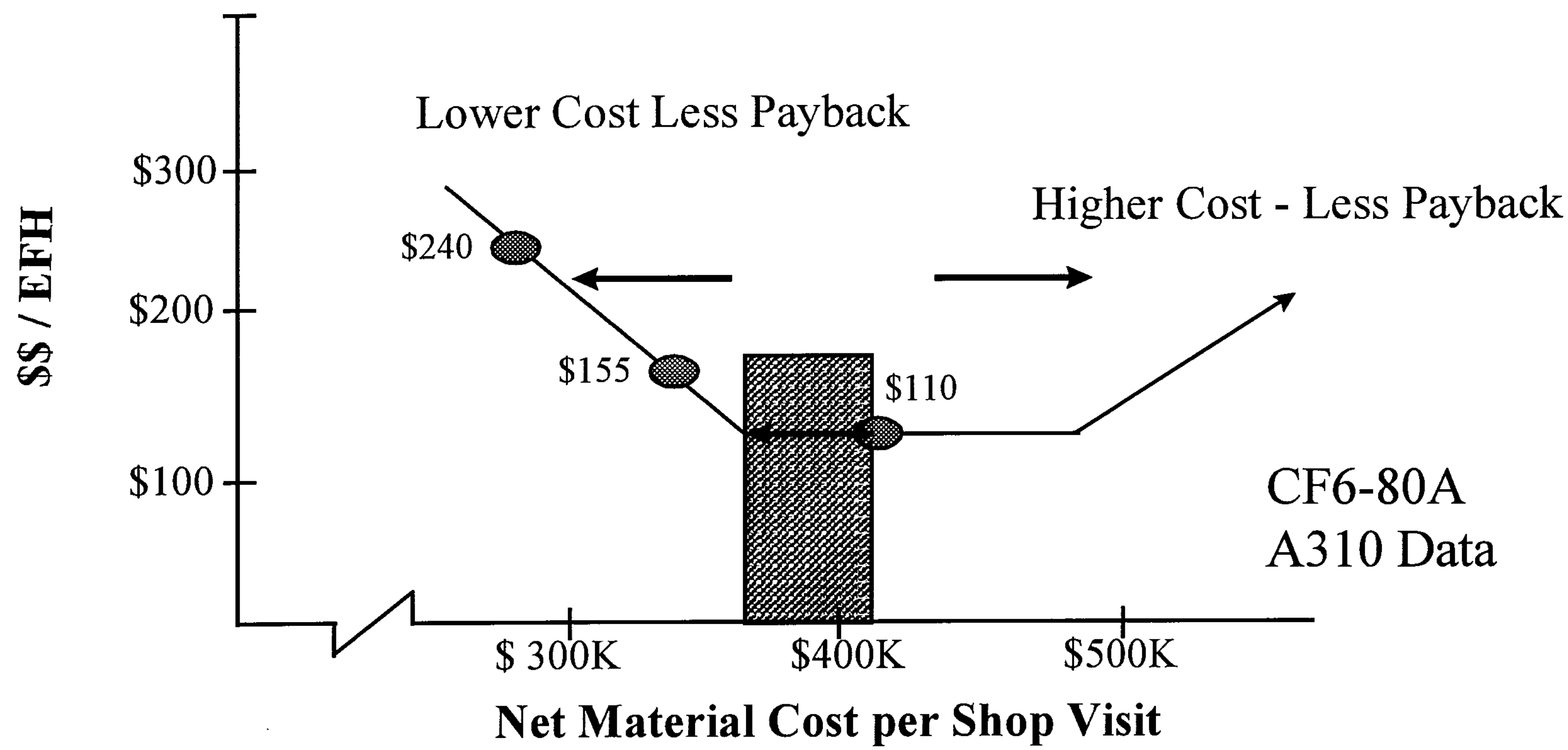
C&R = Check & Repair -- Fix only what drove off wing//Update to next interval
HSR= Hot Section Repair -- Reblade HPT, insp. & repair as necessary on other modules
EHM=Engine Heavy Maintenance -- Restore life for all modules

Maintenance Planning by IPT: Individual Engine Work Scoping

RCM in COMMERCIAL PRACTICE

Propulsion DSO

Work Scope - Value Relationship



30% Increase in Material Cost/Shop Visit =55% Lower Cost/EFH

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

F100 Fighter Engine Family Overview

Engine Model	Thrust-Lbs Class	Engine Quantities	Engine Flt. Hours	Aircraft F-15	Aircraft F-16
F100-PW-100	24,000	1,629	7,241,100	858	
F100-PW-200	24,000	807	3,949,500		658
F100-PW-220/E	*24,000*	*2,257*	*2,488,100*	*307*	*807*
F100-PW-229	29,000	392	318,100	113	109
Total		4,985	13,996,800	1,278	1,574

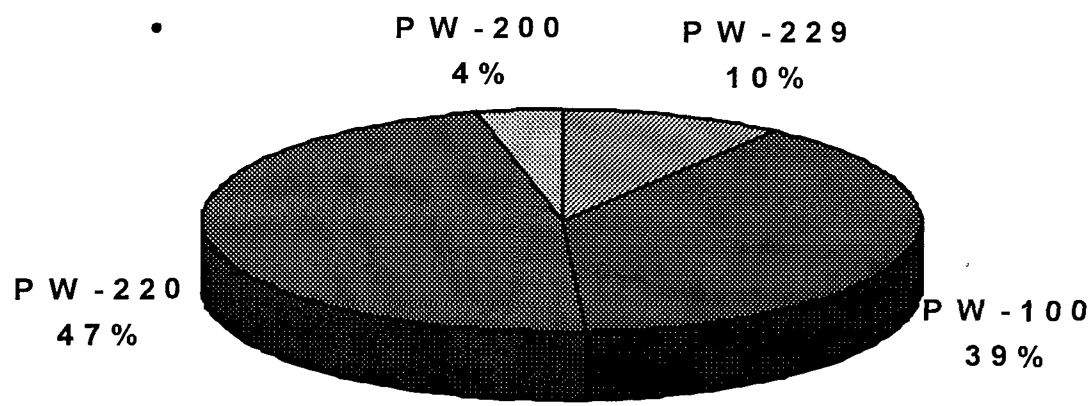
Note: Worldwide except Japan and engines/aircraft in storage at Davis-Monthan AFB

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

USAF F100 Fleet

3000 Active Engines - In Service Since 1974



- F100-PW-100 (1974) powers F-15A/B/C/D
- F100-PW-200 (1978) powers F-16A/B
- **F100-PW-220 (1987) powers F-16A/B/C/D and F-15B/C/D/E**
- F100-PW-229 (1991) powers F-16C/D and F-15E

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Luke AFB 56th Fighter Wing R & M Data - Jan 97- May 98

	Luke	Remaining Fleet (11 Bases)
Engines	211 (26%)	598 (74%)
EFH/month	4161 (36%)	7357 (64%)
UERs	201 (31%)	439 (69%)
SERs	308 (44%)	396 (56%)
UER Rate	3.15	2.92
SER Rate	4.77	2.91
SVR	7.92	5.82
# Shp Vsts/Mo	30	77
TAC/EFH	2.61	2.16
ABLites/EFH	4.22	3.90

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

220/E DEMO IPT

PPGM / PPG Technical Director

RCM IPT Leaders
SAALC/LPF & ASC/LPP

RCM Team Members:
Pratt & Whitney, USAF/ASC, /SA-ALC, /AETC & 56th FW at Luke, Logtec

Control & Metric Tracking Team
- Design of Test
- ELMP
- Maintenance Management Plan
- Metrics (SER, UER, SVR, etc)
- Operational data analysis
- Engine & module tracking
- Mission data
- RCM tracking procedures & plan

Cost Benefits & Hwd Team
- Parts Analysis
- Hardware Availability
- Build Standard
- Cost Accounting
- Cost Benefit Analysis
-

Engineering Team
- Memorandum of Agreement
- Maintenance Instructions
- Performance Trending
- Levels of inspection & repair
- Module & part matching
- Repair expansion
- Life limit extensions
- Special equipment

F100-PW-220/E Demonstration Plan - Overview

- Demo Pilot - 1 Oct. 98 - 30 Sept. 99
- Where - 56th FW (AETC) at Luke with qty. 187 F16C/D220/220E

Approach

- <u>Phase 1</u> (ongoing) - Establish module/engine build policy
  - Identify SVR drivers, determine available fixes, conduct cost/benefits analysis, develop workscope matrix for I & D level, optimize module matching at Luke.
- <u>Phase 2</u> (ongoing) - Implement build policies at SA-ALC and Luke
  - Revise I & D level T.O.s as needed
  - Provide any enhanced I level capability
- <u>Phase 3</u> - Monitor, collect and analyze reliability and cost data
  - Final report by 1 November 99
  -

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

- Demo Objectives -

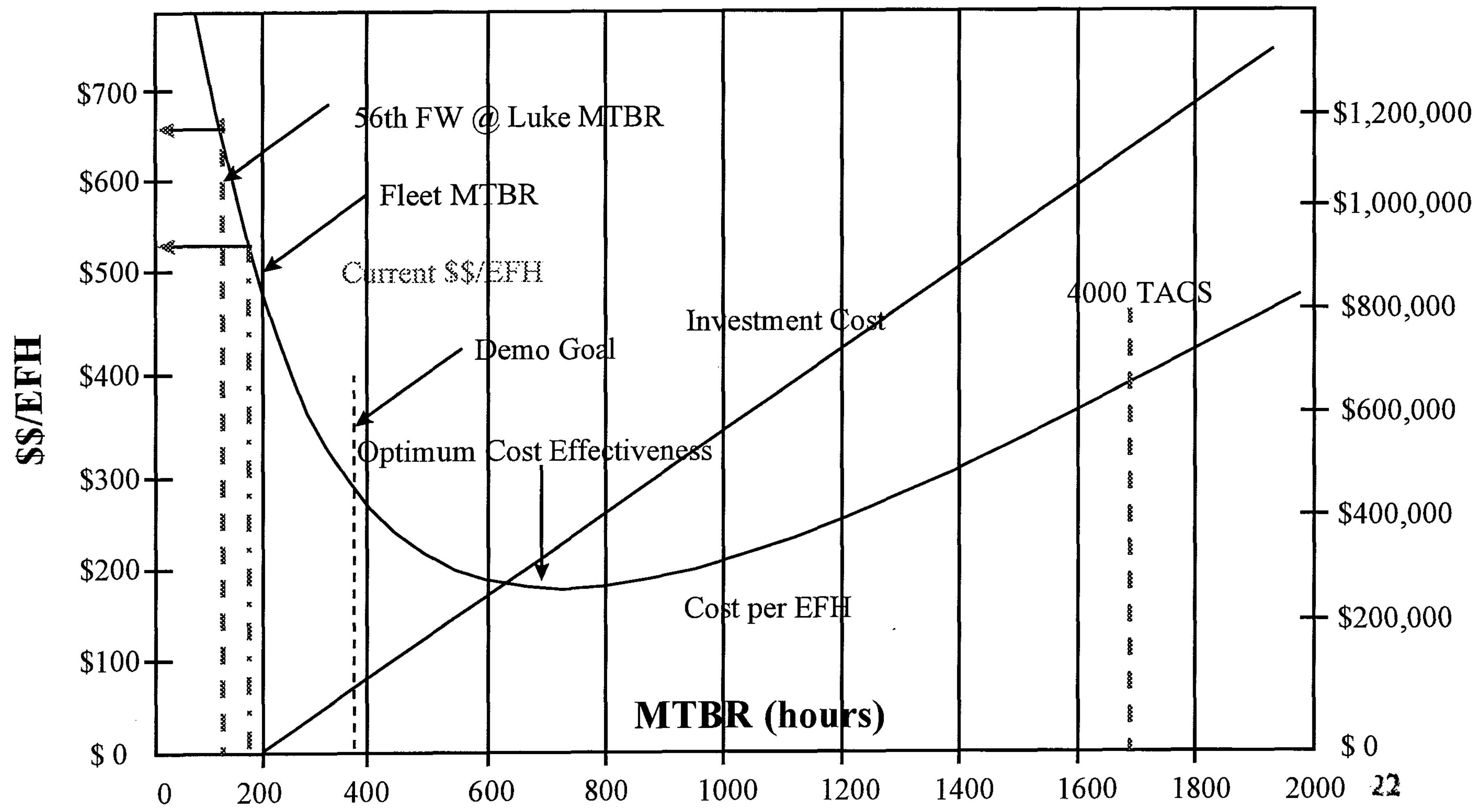
Today (USAF fleet)			Potential	
SER/1000	3.06		SER/1000	2.2
UER/1000	3.07		UER/1000	1.1
SVR/1000	6.13		SVR/1000	3.3
$/EFH	> $510		$/EFH	$280
MTBR	< 200 EFH		MTBR	> 500 EFH
Depot Interval (avg TACS/ unscheduled JEIM Removal)	3K/4K Fan 4K Core 3.5K LPT 2K Aug 1800 MOH GB	(1820) (1850) (1520) (1500) (1250)	Depot Interval (TACS)	4K Fan 4K Core 4K Aug 3000 MOH GB

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Maintenance Cost Theory

Projected Operational Costs Vs Time Between Engine Removal

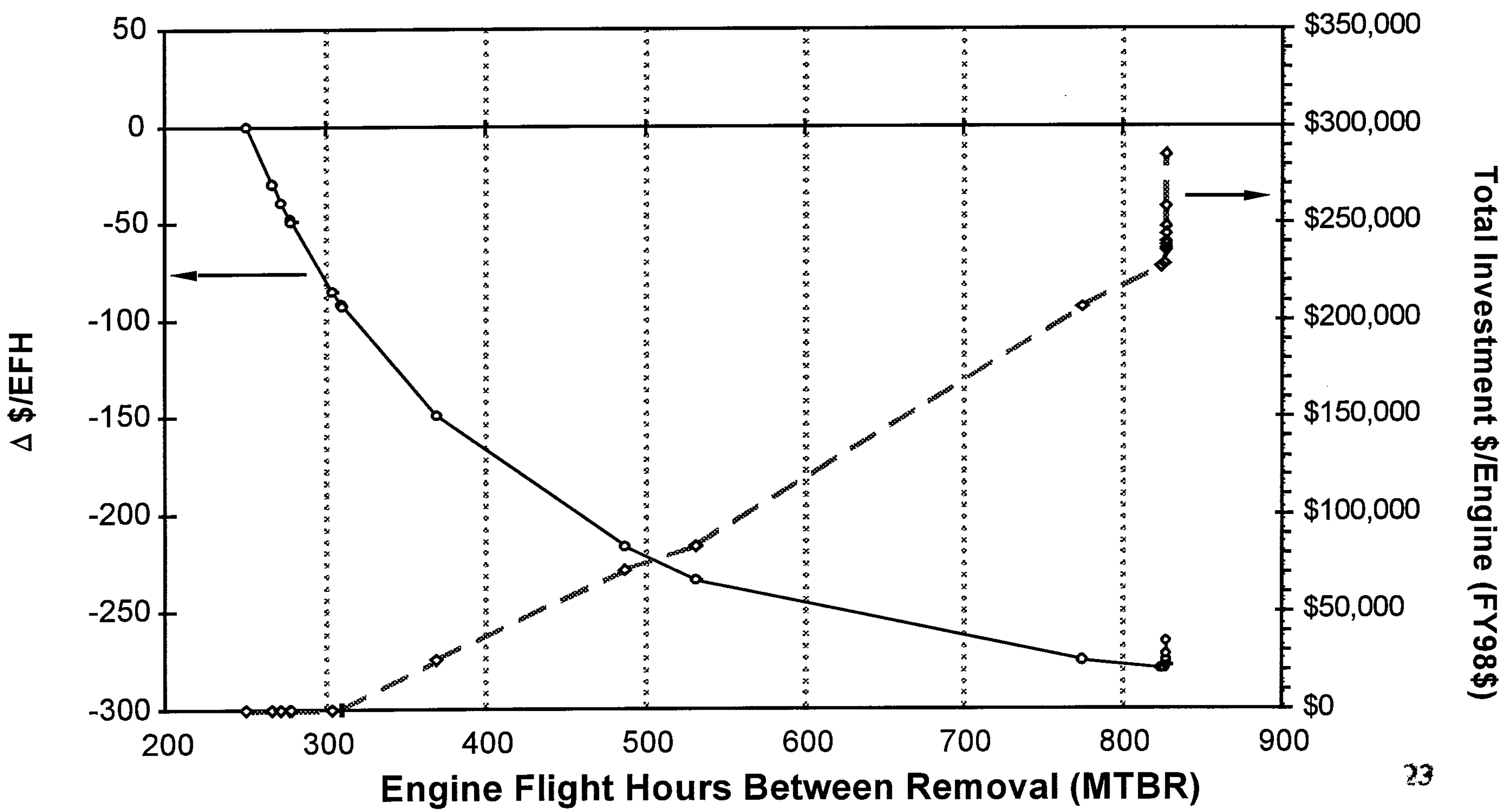


F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Preliminary F100-PW-220 RCM Cost Benefit

JEIM and Depot Tasks Combined



F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Depot Build Standards for Luke AFB RCM Demo

"A" Standard - REP FAN / CORE / LPT / Augmentor

- Delta cost $193K/Engine

"B" Standard - REP FAN / CORE / LPT

- Delta cost - $ 0**

"C" Standard - REP FAN / 220E CORE / LPT

"D" Standard - REP FAN or CORE or LPT

"E" (lead) Standard - All other configurations

** Cost of improvements is negotiated in current overhaul price

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F100-PW-220/E RCM DEMONSTRATION

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Build Standard Recommendations

Fan Module
- REP (4000 Cyc Conf)
  - 3rd Disk/Blades
- Sq Drive CIVV System

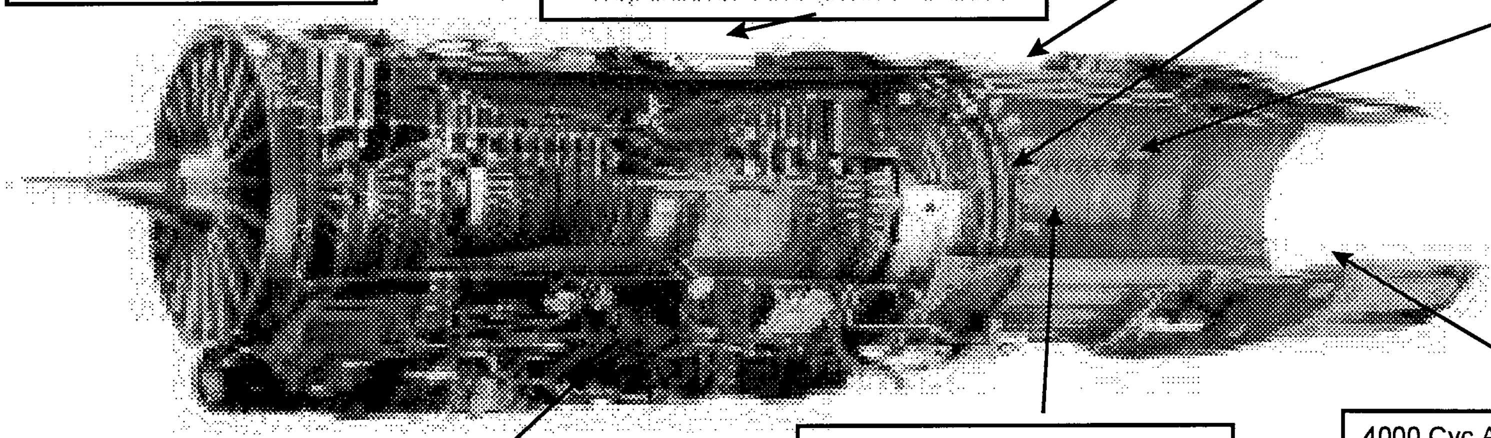
TCTO exists
ReOp/
MOH extension
Funding Required

High Pressure Compressor
- -220 Configuration (employs MOP)
  - ID Seals/Honeycomb
  - Blade Length
  - 220 Aero
- Zero Time 4th Blades
- 2 Degree RCVV DEEC Logic
- RCVV Bushings
- 13th Stage Bleed Rods
- Ni Braze Fuel Nozzles
- Fuel Manifold 11J Clamps
- Reop Diffuser Case (Mount Pin Boss

Externals & Controls
- Hi Temp CENC
- Anti-ice Valve Kit
- 2.5.3/5.3.0 DEEC
- 2.4.0 EDU
- FTIT Probe Check
- Upgrade ENPT
- Nomex Cables
- PDC Stacked Orifice

High Pressure Turbine
- MOP (new/ 2nd Stg Blades
- Aerex 350 Pins and Collars
- 2nd Stg BladePi Tape Measurement
- HPT Assy/Disassy Tooling for JEIM

#5 Bearing Compartment
- Redesigned Tubes
- Anti-siphon hardware



Lube and Gearbox
- 1800 MOT Gearbox (extend to 2000 MOT)
- Improved Oil Servicing Procedures
- Improved Lube System

Low Pressure Turbine
- REP Turbine (4000 Cyc Config)
  - 3rd Disk/Blades
  - 4th Disk/Blades
  - 3rd Vanes
  - 3rd BOAS
  - 2nd BOAS Support
  - Rim Seal

4000 Cyc Augmentor Module
- 12 new parts
- 24 re-operated parts
- Actuator Gear & Ball Screw
- Clean Spray Rings
- Self Cleaning Spray Rings (1,2, 4)
- Cut Back Fingerseals

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F100-PW-220/E RCM DEMONSTRATION

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Master Schedule

	Task Name	Start	Finish
1	Collect and analyze SVR/UER data	2/2	2/27
2	SVR/UER Drivers module	2/2	3/31
3	Establish goals	3/18	3/31
4	available design fixes	3/20	4/30
5	Establish hardware costs for fixes	5/11	5/31
6	Establish RCM CONOPs	5/29	6/23
7	Conduct RCM cost benefit analysis	6/24	7/14
8	Establish the "gold standard" engine	7/1	7/22
9	Identify required changes	6/11	7/22
	Assess supportability/budget	7/15	7/29
	Ahead	8/14	
	funding	8/14	9/15
	Update/Revise TOs	9/16	10/15
14	RCM build and	6/16	10/15
	independent collection & analysis	9/30	10/29
	Perform demonstration pilot	10/1	9/30
17	Provide Final Report	11/1	

Timeline: Jul '97 | Oct '97 | Jan '98 | Apr '98 | Jul '98 | Oct '98 | Jan '99 | Apr '99 | Jul '99 | Oct '99 | Jan '00

6

Interactive Electronic Technical Manual (IETM)

NDIA CONFERENECE

September 16, 1998

Robert Worsham
New Programs Manager
Instructional Systems & Technical Publications

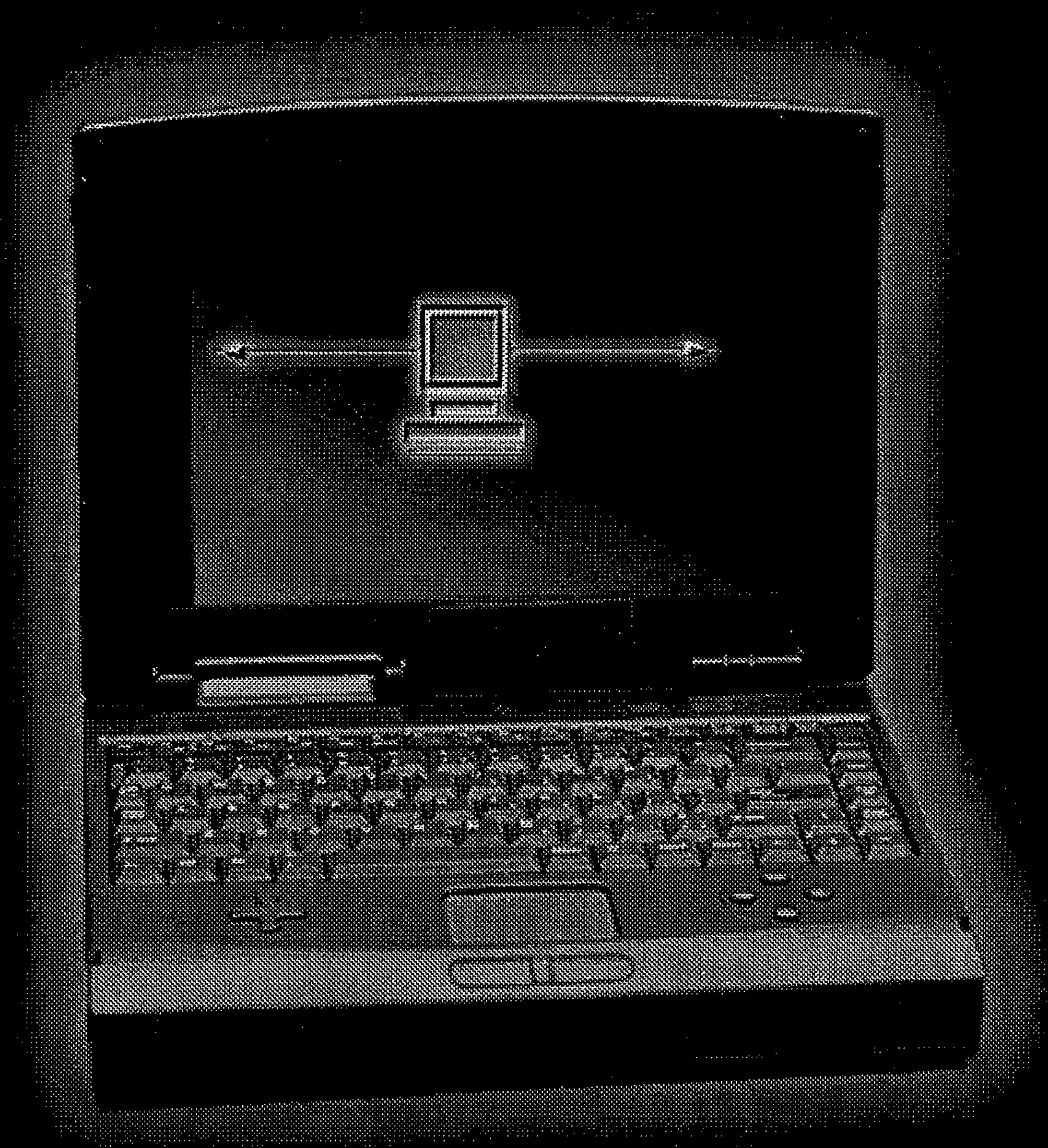
BOEING

Interactive Electronic Technical Manual

- History
  - Boeing IETM Leadership
    - U.S. Navy/Marine Corp. Feasibility Study - 1994
    - AH-64D Apache Longbow - Fielded - July 1998
    - F/A-18 E/F SuperHornet - November 1998
    - AH-64D Apache Longbow FMS - March 1999
    - F/A-18 C/D Hornet - October 2001
    - F/A-18 C/D Hornet FMS - 2002
    - Several military and commercial endeavors in-work
    - Meritorious Achievement Award from the American Helicopter Society in May, 1998

Class I, II, III

- Electronic Technical Manual (ETM)
- Electronic Replication of Paper Manual
- Data Access Expedited by Page Turner and Hyperlinks
- Maintainer Searches for Data
- Mid MMH/FH High False Removals



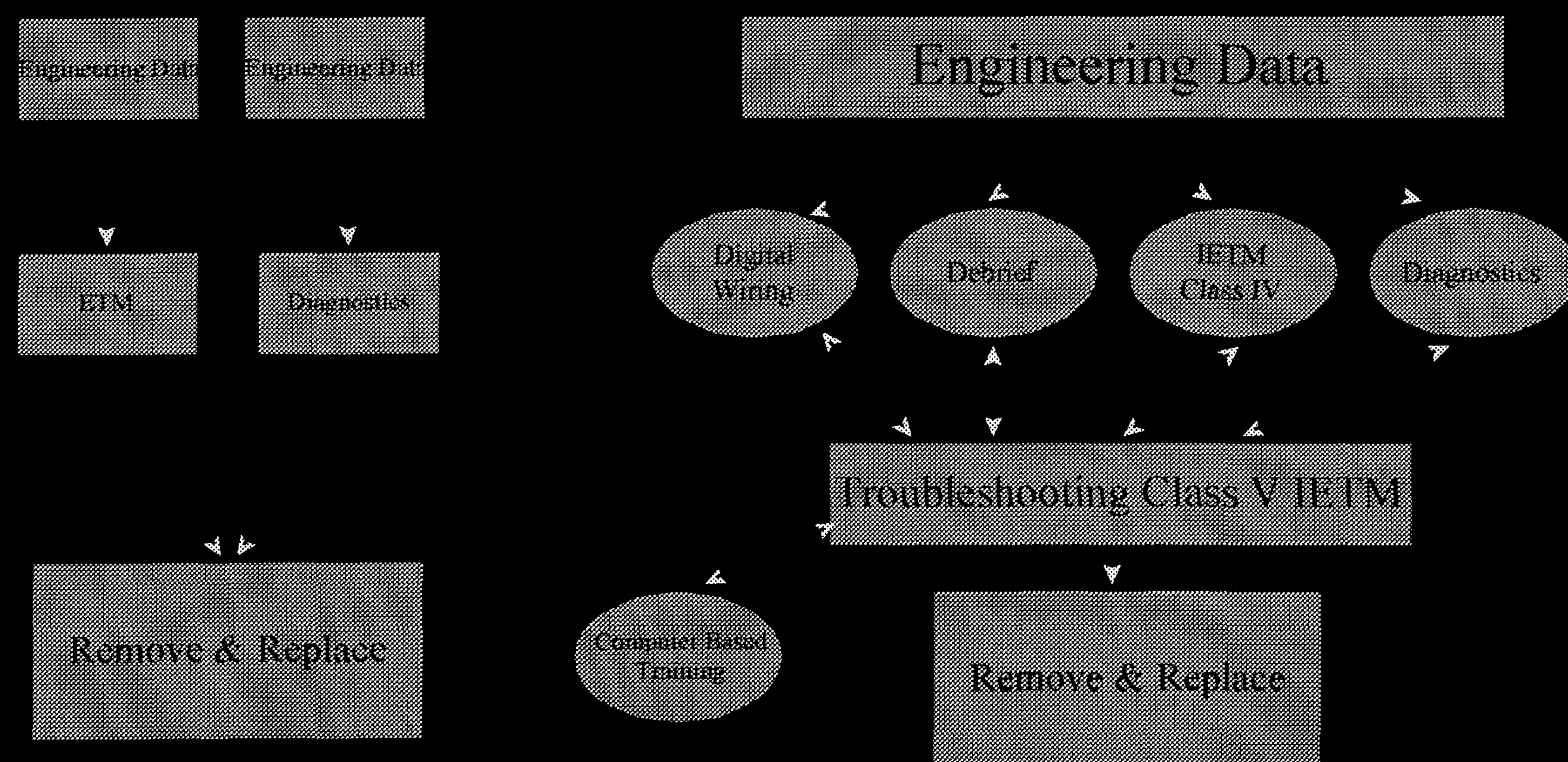
Class IV

- Interactive Electronic Technical Manual (IETM)
- Fully Interactive IETM, Provides Needed Data to Maintainer, Leads Maintainer Down the Correct Maintenance Path. Allows for Reduced Training
- Ease of Access to Required Information
- Reduction in MMH
- Low False Removals

Class V

- Class IV IETM and Electronic Infrastructure
- IETM Linked to EQUIP and Maintenance Network
- Integrated with Equipment Diagnostics
- Expedites Trouble-shooting, Spares Ordering and Maintenance Planning
- Increases Equipment Availability

Interactive Electronic Technical Manual



BOEING

Interactive Electronic Technical Manual

- Boeing IETM Capabilities
  - Authoring and End-User
    - Complete fault structure
    - Procedural data
    - Graphics with *Hotspots*
    - Automated linking to external modules (Debrief, wiring system, look-up tables)
    - Expert and Novice modes

Interactive Electronic Technical Manual

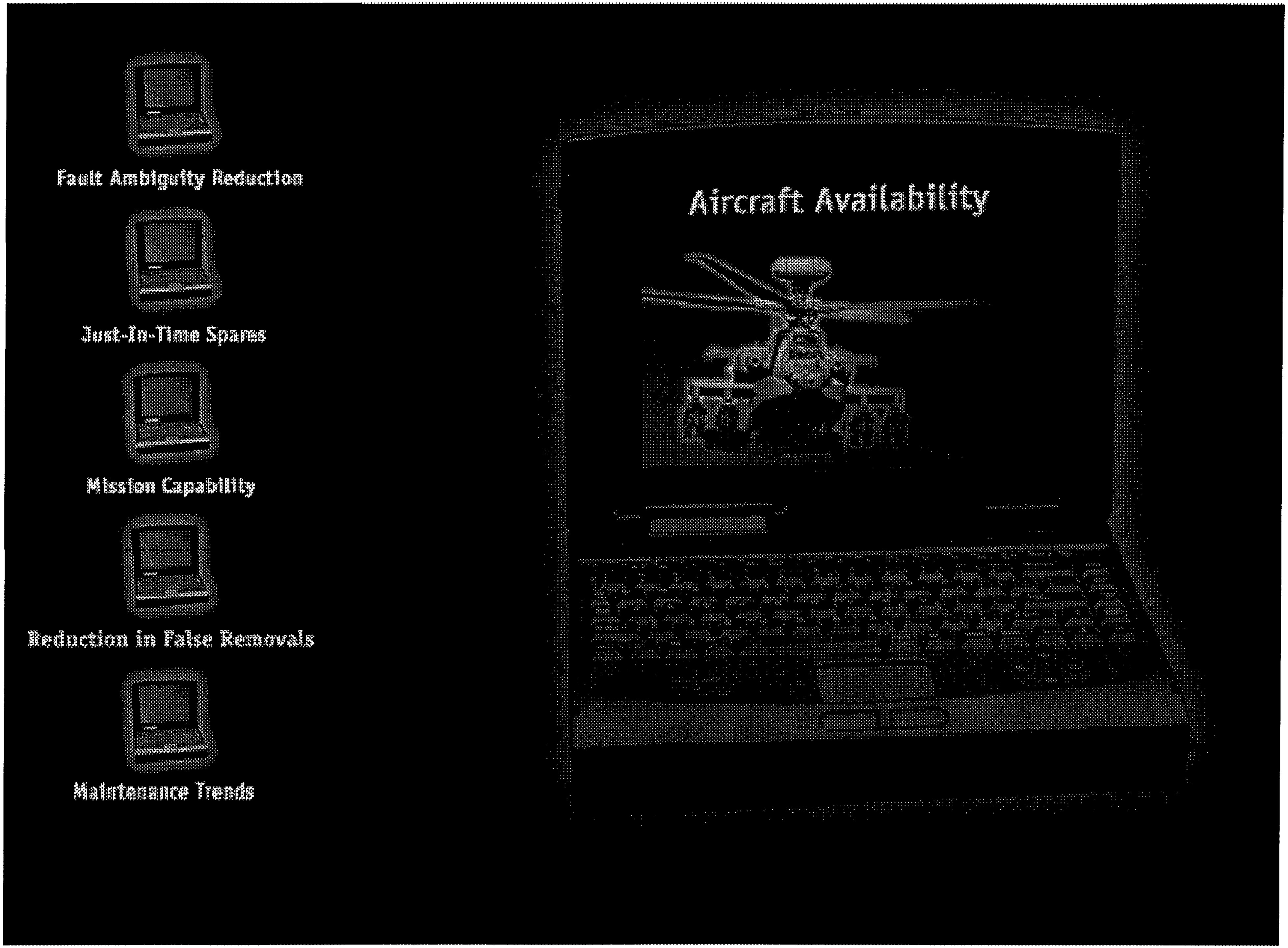
- Boeing IETM Capabilities
  - Authoring and End-User
    - Context filtering by effectivity
    - DBMS
    - Support of multiple authors simultaneously (currently over 60 authors per on two weapon system programs)
    - Web implementation
    - Automated Torque Wrench

BOEING

Interactive Electronic Technical Manual

- Studies
  - Data Capture
    - Naval Surface Warfare Center
      - Carderock Division
      - Aviation Maintenance Environment (AME) Cost Benefit Report (May, 1998)

"Reduced distribution and updating costs reclaim 73% of IETM implementation investment".


Fault Ambiguity Reduction
Just-In-Time Spares
Mission Capability
Reduction in False Removals
Maintenance Trends
Aircraft Availability

BOEING

Interactive Electronic Technical Manual

- Studies
  - Data Capture
    - Ft. Hood, TX
      - 1st Battalion, 227th Aviation Regiment
      - FSR and military personnel are starting to measure data
      - Goal is to finish in 90 days
      - Distribution of report and method pending
    - Lemoore, CA
      - OPEVAL
      - Measure accountable data
      -

BOEING

Interactive Electronic Technical Manual

- Boeing's IETM is Available for Use
  - Data content development and end-user licensing
  - COTS - Licensing, Training, Maintenance Support, and Cultural Change
  - Data content development and/or data content development and build customer computer hardware and software infrastructure while supporting cultural change
  -

BOEING

Robert Worsham

New Programs Manager
Instructional Systems & Technical Publications
Aircraft & Missiles
St. Louis, MO

314.233.6751

robert.w.worsham@boeing.com